Universidade de Aveiro Departamento de Comunicação e Arte
2009

Samuel de Jesus Almeida

Análise do Movimento Ocular na Concepção e Desenvolvimento dos Videojogos

Augmenting Video Game Development with Eye Movement Analysis

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Dissertação apresentada à Universidade de Aveiro para cumprimento dos requisitos necessários à obtenção do grau de Mestre em Comunicação Multimédia, realizada sob a orientação científica do Doutor Óscar Emanuel Chaves Mealha, Professor Associado do Departamento de Comunicação e Arte da Universidade de Aveiro e sob a co-orientação da Doutora Ana Isabel Barreto Furtado Franco de Albuquerque Veloso, Professora Auxiliar do Departamento de Comunicação e Arte da Universidade de Aveiro.

Dedico este trabalho aos meus pais cujos esforços e sacrifícios me permitiram realizar tudo que até hoje fiz e cujos ensinamentos e dedicação fizeram de mim a pessoa que hoje sou.

I dedicate this work to my parents whose efforts and sacrifices allowed me to accomplish everything I’ve done and whose teachings and dedication made me the person I am today.

o júri

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agradecimentos

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Thank you all!

palavras-chave Atenção Visual, Avaliação de Videojogos, Eye Tracking, Usabilidade

resumo

A indústria dos vídeo jogos é actualmente uma das mais valiosas e lucrativas do género. Como se espera de qualquer membro activo desta indústria, os produtores de vídeo jogos aspiram a obter uma quota desse mercado e das receitas.

Hoje, a exigência relativa ao lançamento de vídeo jogos é tal que, por vezes, uma das etapas cruciais do desenvolvimento do produto é preterida – a avaliação da usabilidade – o que resulta em jogos de menor qualidade. Ainda, os vídeo jogos que são avaliados acabam por o ser à custa de métodos que não são totalmente correctos e que não respeitam à unicidade do *media*.

O presente trabalho surge, portanto, com o objectivo de apresentar uma nova metodologia que vá ao encontro do referido problema. A metodologia proposta é uma parte de um estudo empírico que contou com participantes com distintos níveis de experiencia com vídeo jogos e que fez uso de dois instrumentos: um questionário e em segundo lugar, uma tecnologia que não gera consenso – o *eye tracking* – um método que mensura os movimentos e as posições do olho. Os dados obtidos através dos questionários bem como os resultados do *eye tracking* foram analisados e serviram de base para o objectivo maior deste estudo: o desenvolvimento de *guidelines* (linhas orientadoras) que possam assistir na melhoria da concepção e do desenvolvimento de vídeo jogos.

keywords

Visual Attention, Video Game Evaluation, Eye Tracking, Usability

abstract

The video game industry is presently one of the most valuable and lucrative of its kind. As is expected from any active member in this industry, video game developers aspire to secure a share of that market and income.
Currently, the demand to deliver video games is such that at times, one of the most important moments of product development is overlooked – usability evaluation – resulting in less enjoyable or playable video games. Furthermore, those that are evaluated are done so at the cost of methods that are not completely accurate and that do not respect the uniqueness of the media.
The present study emerges, therefore, with the objective of presenting a new methodology that can challenge the mentioned predicament. The proposed methodology is one part of an empirical study that counted with participants of various gaming experiences and made use of two instruments: a questionnaire and secondly, a technology many have yet to accept – eye tracking – a method capable of measuring eye movement and eye positions. The acquired data from the questionnaires along with eye tracking results were analyzed and served as the basis for the greater objective of this study: the development of guidelines that can assist in the augmentation of video game development.

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list of acronyms

AI	Artificial Intelligence
CNS	Central Nervous System
COD	Call of Duty
EOG	Electro-OculoGraphy
FPS	First-person shooter
HCI	Human Computer Interaction
HEP	Heuristic Evaluation for Playability [from: (Desurvire, Caplan, & Toth, 2004)]
POG	Photo-OculoGraphy
PoR	Point of Regard [from: (Duchowski, 2007)]
RPG	Role-playing game
TRUE	Tracking Real-Time User Experience [from: (Kim et al., 2008)]
UCD	User-centred Design
UIE	User Initiated Events
VOG	Video-OculoGraphy
UAV	Unmanned Aerial Vehicle

1. Introduction

1.1. Research problem

Why worry about video games? The question is certainly a legitimate one and, looking at some of the facts, we can understand that it is most definitely relevant.

In an industry where millions of dollars are spent and generated every year, the need for existing and surfacing video game development companies to secure their portion of the market is greater than ever. In 1996, the United States Entertainment Software Industry (ESA)[1] registered that, in the United States of America alone, approximately 74 million video game units were sold along with $2.6 billion in sales. A decade later, current information indicates that the number of computer and video game units sold is nearly 268 million and that the sales revenue is just under $10 billion (ESA, 2008). According to a PricewaterCoopers[2] study, by 2010, worldwide sales related to video games will reach $46.5 billion due to the arrival of new handsets and next-generation consoles (Hartig).

Brandon Curiel, President and CEO of Venan Entertainment, describes the phenomenon as, "*You have the older gamers that haven't stopped playing, and you have younger kids that are getting into it every day. (…) Each year, the market just expands, and it's going to keep expanding for, well, a long time*." The irrefutable fact is that the number of people playing video games is constantly growing and changing.

If in fact by the following year the video game industry hits the mentioned number, it seems reasonable to affirm that acquiring a share of that revenue is crucial for video game developers if they intend to remain active in the industry. One of the main factors that can help in attaining this goal is the development of a well planned video game.

[1] The Entertainment Software Association (ESA) is the U.S. association exclusively dedicated to serving the business and public affairs needs of companies that publish computer and video games for video game consoles, personal computers, and the Internet. [website: http://www.theesa.com/]

[2] PricewaterhouseCoopers is a Professional services firm, working in auditing and assurance, crisis management, human resources, performance improvement, tax and transactions. [website: http://www.pwc.com]

Some videogames and companies (e.g. Electronic Arts[3]) have established their proper status over the past years. However, for new uprising companies and game titles, quality makes all the difference. To achieve success, a video game must be appealing to the consumer. This is done by delivering quality on all game aspects such as the gameplay, the mechanics, the interface (Clanton, 1998), the interaction as well as the experience.

The demand to deliver successful games, however, results occasionally in the development of *weak* games in terms of gameplay, mechanics or interface. This in part is due to the fact that many video games are developed and released without having been properly evaluated, if evaluated at all. This represents, in fact, one of the biggest problems in the video game industry.

To overcome the mentioned limitations, research and other projects are being conducted that propose solutions and strategies for developing more quality video games. Nevertheless, much of the existing research focuses on the use of solutions that are traditionally applied in regular product and system assessment. Despite this approach not being inadequate, it is, on some levels, limited. Video games are *products* of a specific nature and require specific development and evaluation. The use of game heuristics, based on existing product and system evaluation heuristic guidelines, while being useful, do not attend to all existing game usability issues as well as other video game aspects previously mentioned. For that motive, it is necessary to look into other technologies and solutions that can help in overcoming the referred limitations.

With that in mind, the use of eye tracking enters the scene as well as presents itself as the soul of this study as it is a *new* technology that can assist in evaluation. It has been used in cognitive and psychological studies; used to evaluate traditional media such as static web pages for web usability and now, it presents itself as a technology to evaluate video games. Eye trackers provide data that can be useful for evaluating certain aspects of video games and the objective of this study is to prove its validity.

Nonetheless, with eye tracking we have a technology that, despite its usefulness, may not be assumed as a technique that alone can solve all usability evaluation problems, especially in what concerns video games. It cannot be forgotten that the eye tracker reproduces and indicates where we are looking but even so, despite the eye being the window to our mind and soul, eye tracking cannot represent what we feel and we think.

For that reason, any results returned by an eye tracking study must always be kept within the context in which they were performed due to the specificity of the technology at hand.

1.2. Research question

Having briefly contextualized the current situation associated to the video game industry as well as presented the technology intended to study; the following question is proposed bearing in mind the questions and concerns mentioned above:

> *In what way can the analysis of the ocular globe movement contribute to the development of guidelines that can assist in the evaluation of enjoyment in video games?*

The reason for proposing the evaluation of *enjoyment* rather than usability relates to the specificity of video games as mentioned above. Due to their nature, video games are products developed for leisure purposes

[3] Electronic Arts [Website: http://www.ea.com]

as opposed to practical everyday uses. For that reason, it seems reasonable that the enjoyment they offer through their gameplay require that their particular mechanics and interface be assessed. As stated, eye tracking alone cannot solve all the problems nor present all the solutions. Nonetheless, eye tracking may be suggested as a valid option for discovering usability and other specific game problems especially if used alongside other usability evaluation techniques such as observation and queries – two techniques presented by Dix et al (Dix, Finlay, Abowd, & Beale, 1998) – and their respective instruments (e.g. think-aloud protocol for the observation technique and questionnaires for the query technique).

1.3. Objectives

The following project presented a series of objectives that met the needs of the project's problem as mentioned above. Those objectives were:

- To identify the potentialities associated to the use of eye tracking technology in a usability evaluation process;
- To identify currently used methods for evaluating usability in a video game context;
- To identify and build a study case;
- To evaluate and validate a video game evaluation methodology;
- To construct a series of guidelines that can assist in the evaluation of video game enjoyment.

The project's overall finality was, as briefly presented in the last point, to develop a list of guidelines that can be used in video game development as well as usability studies.

1.4. Methodology

A methodology can be described as the framework for research which, when complying with a group of standards, makes it possible to select and articulate techniques designated to aid in the development of the empirical process validation (Pardal & Correia, 1995). The methodology applied during the project was the exploratory method as well as, at times, the descriptive method. The first is a method in which a specific area of study that is somewhat incompletely studied is, as the name indicates, explored; whereas the second focuses on thoroughly describing a specific study object (Carmo & Ferreira, 1998, p. 47). The methodology commenced with the elaboration of the first part of the project – the state of the art – that is, the collection of facts and information related to the area of usability and video games. The state of the art part was elaborated through the use of bibliographical research. Furthermore, the data collection procedure was executed through the elaboration of a case study where participants also played a video game so that eye movement data was acquired through the use of an eye tracker.

In terms of data collection, two techniques were applied: inquiry and observation. However, a technique on its own, eye tracking – through the use of the Tobii T120 Eye Tracker – was also used to collect quantitative data related to user eye movements. The inquiry technique, characterized as being a process in which information is attempted to be discovered in a systematic manner (Carmo & Ferreira, 1998, p. 123), was applied using the questionnaire instrument. In addition, the observation technique was also taken into consideration so that eventual problems and information observed during the case study would be written for further analysis.

In what concerns the study participants; the study target group was composed of 41 participants. For typical experimental evaluation studies, the number of participants used should be in enough quantity that they can stand in as a representation of the general population (Dix, Finlay, Abowd, & Beale, 1998, p. 416). As the general population of video game players is vast, a minimum number of 15 participants were felt to be sufficient. However, as mentioned, the final number of participants used in the study exceeded that value. Furthermore, video game playing experience varies from player to player. For that reason, participants with different aptitudes for playing games were selected and further divided into three different groups: novice or inexperienced players, regular or casual gamers and hardcore gamers. The process of dividing participants into three distinct groups was done through the use of a questionnaire to assess each participant's history and comfort with playing games as well as other valuable information.

The next part of the methodology consisted in the participants familiarizing themselves with the eye tracking technology, the video game, as well as the technological limitations, so that the final study produced more reliable results. To do so, participants completed two distinct tasks in the video game Call of Duty 4: Modern Warfare. The first task allowed the player to familiarize him/herself with the game as well as allowed the players to get accustomed to the head movement limitations the eye tracker imposes.

The study consisted, therefore, in the participants playing the First-person shooter video game Call of Duty 4: Modern Warfare while completing two distinct tasks for 5 minutes. The complementary use of the think-aloud process while the players are interacting with the game was a possibility but, as it was thought that the use of this technique simultaneously with the eye tracker would influence the participants' interaction and cognitive workload (Johansen, Nørgaard, & Rau, 2008), the idea was set aside. Bearing that in mind, participants were asked to fill out a questionnaire at the end of their participation to collect other pertinent information related with their game experience.

The next step in the project's methodology consisted in collecting all the data and analyzing it. Quantitative eye tracking metrics such as fixations and saccades (Jacob & Karn, 2003) supplied by the eye tracker and software were processed to understand in what context they took place as well as what results they produced. In addition, qualitative results acquired through the post-study questionnaires were thoroughly analysed to understand in what way both quantitative and qualitative data are linked.

The final and most challenging element of the methodology completed was the development of guidelines that can assist in augmenting video game development. Making sense of all the data – both quantitative and qualitative – and translating the problems users experienced as well as the suggestions they offered into comprehensible and valuable ideas for usability evaluation was a task that required its own validation and testing. The ideas proved to be useful for a similar evaluation context were written up as guidelines for augmenting video game development.

1.4.1. Model of analysis

Succinctly, the purpose of the model of analysis is to clarify and describe in a clearer manner the concepts present in the research question as to organize the research process which will result in the gathering and analysis of data (Quivy & Van Campenhoudt, 2008). The model of analysis is therefore organized into concepts, dimensions – through which the concepts are analysed – and indicators, which are easily identifiable. Retrieving once more the research question – *In what way can the analysis of the ocular globe movement contribute to the development of guidelines that can assist in the evaluation of enjoyment in* *video games?* – the concepts that can be extracted are: ocular globe, guidelines, evaluation, enjoyment and video games.

Ocular globe refers to or is part of the eye; it is responsible for the faculty of vision and is made up of various components. Guidelines refer to a series of indications or procedures that can be used for a specific procedure. Evaluation refers to the act of assessing the presence of certain elements necessary to a system's functionality. Enjoyment refers to the emotional state in which a person feels content receives pleasure through the execution of an activity. Finally, video games are an interactive media source designated to entertain their public.

The five presented concepts can be broken down into various dimensions and indicators as can be seen in Table 1. The ocular globe concept is broken down into the dimensions components and functions. The guidelines concept is liked together with the categories dimension. The evaluation concept has two dimensions: game experience and typologies. The concept of enjoyment is broken down into the source dimension and finally, the video games concept is divided into the genres and characteristics dimension.

Concepts	Dimensions	Indicators
Ocular globe	Components	What are the main components of the ocular globe?
	Functions	What are the functions of the ocular globe and its components?
Guidelines	Categories	Into what categories are development guidelines distributed?
Evaluation [Usability]	Game Experience	How is game experience evaluated?
	Typologies	What are the existing/traditional (usability) evaluation typologies?
Enjoyment	Source	What are the sources of enjoyment in video games?
Video games	Genres	What video game genres are available on the market?
	Characteristics	What are the main characteristics of those genres?

Table 1 - Concepts, dimensions and indicators of analysis model

Once the analysis model is built, defining hypothesis can assist in the elaboration of a more precise and rigorous study (Quivy & Van Campenhoudt, 2008). Therefore, bearing in mind the concepts established and the dimensions and indicators that are associated to these, the following hypothesis can be presented.

- The movements of the ocular globe represent valid information that can be used in the elaboration of guidelines that can assist in the evaluation of video games.

- Existing (usability) evaluation methods are valuable to the development and evaluation of enjoyable video games.

- Ocular globe movements can be tracked identified and present themselves as a method of understanding enjoyment in video games.

Of the presented hypothesis and bearing in mind the study objectives, the validation of the first is the main goal of the present project.

1.5. Personal motivations

With more than two decades of memories to account for, some of the most enjoyable and significant moments in my life to date were those when in company, as a child and even as an adult, I turned away from the real world and found a form of distraction in a distinct, virtual world – a world of video games.

These worlds in which millions of people around the planet invest their time are, today, just as an important source of entertainment as is a weekly television series or a Friday night at the movies. Whatever the source of entertainment, their initial objective is, as their designation suggests, *to entertain*. Therefore, when any of these sources fails to entertain, one asks him or herself, *what went wrong?*

Having always been interested in and enjoyed video games; as well as having always, with moderation, played them, when having found aspects of video games that I felt were underachieved, I found myself questioning exactly what went wrong and how that particular aspect could have been better.

When the possibility of developing a project and a study that focused on video games presented itself, there were few doubts in my mind that this project would definitely be worth the effort. In fact, the only serious question that surfaced was, among the many possibilities associated to video games, what nature of project to develop.

1.6. Document structure

The following dissertation is organized into three different parts. Part one corresponds to the state of the art; part two is relative to the empirical study and part three, to the study conclusions. Each of these parts is in turn composed of various sections. However, these three parts follow an introduction to the study.

The introduction is divided into 6 parts: the research problem, the research question, the project objectives, the project methodology, personal motives behind the execution of this project and finally, the present section, the document structure. The research problem brings to the reader's attention the current status of the video game industry, video game evaluation and therefore, the relevance of the study. The research question section justifies the question that serves as the backbone for the present study whereas the objectives section presents a list of objectives for the study itself. The methodology section is a breakdown of the methodology that was applied during the course of the study while the personal motives justify the reason for having elaborated this study. Finally, the document structure enlightens the reader on the composition of this dissertation.

The first part of the dissertation is therefore the State of the Art which in turn also contains several sections: the human visual system, including eye components and functions as well as a taxonomy of eye movements; a list of eye tracking systems as well as the pros and cons of the technology; a look at the area of usability; video game genres and an analysis of the First-person shooter genre; finally, the last part of section 1 looks at some of the existing research and projects related to video game evaluation.

Moving on to part two, the empirical study; this section is made up of two parts: the description of the case study that was executed and secondly, the data analysis and results. The case study chapter includes the characterization of the target group as well as the study object, the protocol that was built, the technological setup that was necessary to execute the study and finally, the instruments used to gather data. The data analysis and results chapter includes the presentation of the results obtained via those instruments, the analysis and discussion of those results and finally, the presentation of the guidelines that were elaborated as a result of the study.

Finally, and to conclude, the last part of the document is relative to the conclusions. Here, several aspects of the study were revised and analysed to determine to what extent this work can be continued.

part one
state of the art

2. The Human Visual System

Of all the senses, sight must be the most delightful (Book of Famous Quotes, 2009). Helen Keller, one of the most renowned women of the 20th Century, stated these words, having herself been deaf and blind for almost all her life. Being so, even she understood the value and importance of arguably the most important of the five traditional senses defined by Aristotle (Kohler & Broydé, 2002).

2.1. Eye Components & Functions

Extracting light from the world, filtering it and transforming it into something understandable is the aim of the visual system. It is the eye and its components that make vision possible.

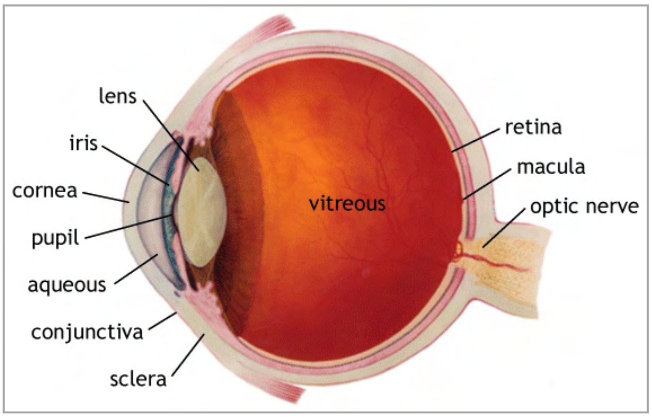

Figure 1 - Anatomy of the Eye [retrieved from: (Eye Anatomy, 2008)]

The human visual system is much more complex than what Figure 1 offers. However, the labels presented are an indication of some of the most important parts of the system that make sight possible.

The cornea is the transparent and simultaneously outermost part of the eye. Located over the iris, it is approximately ½ a millimeter in thickness. The cornea and the lens are similar in structure and in function to the lenses of a photo camera. Together, they are responsible for the ability of focusing by the refraction of light at specific points on the retina. However, the lens plays a more definitive role in adjusting the focus of objects at various distances (Hubel, 1995, p. 34).

The iris is a circular shaped part of the eye responsible for controlling the quantity of light available to be processed by the inner eye. When light intensity differs, the iris responds by contracting in large quantities of light or expanding in smaller quantities - this serves to allow the eye to focus on the object at hand. The space at the centre of the iris is known as the pupil - it is the *hole-like* structure that light passes through in order to get to the retina.

Consistent with the camera analogies, the retina represents what the film does for a photo camera (Segre). The retina converts light waves (or light energy) that enters our eyes into nerve signals and allows us to see in the most various types of conditions. The retina discriminates wave-length so that we can ultimately see colour (Hubel, 1995, p. 36) once the signal is sent via the optic nerve to the visual cortex located at the back of the brain.

The retina, similar to many other structures in the Central Nervous System (CNS) has the shape of a plate and is approximately ¼ of a millimeter thick. It is composed of 3 separate layers of nerve-cells that are held together by two layers of the synapses made by the axons and dendrites of those nerve-cells (Hubel, 1995, p. 36).

The outermost part of the retina is composed of the ganglion cells. The ganglion cells' axons join together at the optic disc of the eye and part from there to form the optic nerve.

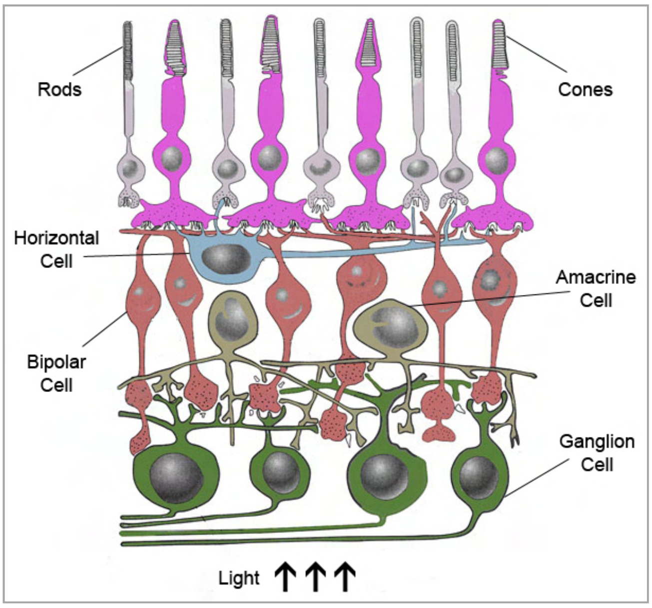

Figure 2 - Anatomy of the Retina [retrieved from: (The Visual System)]

The middle layer of the retina contains three types of nerve cells as visible in Figure 2. The specified neurons are called bipolar cells, horizontal cells and amacrine cells. Bipolar cells receive input from the receptors; horizontal cells are responsible for connecting the receptors and bipolar cells, a connection that is established in parallel to the receptor cells. Finally, the amacrine cells are responsible for connecting the ganglion layer to the bipolar cells (Hubel, 1995, p. 37).

At the innermost part of the retina lies a layer of cells that contain the light receptors: the rods, responsible for vision in low light and cones, responsible for colour vision and detail. In this grouping of cells there are approximately 100 million rods and 7 million cones (Bianco, 2000). Just as their names suggest, the outer section of rods are long and thin whereas the same section of cones have a cone shaped structure.

The outer segments of both rods and cones contain photosensitive chemicals. In the rods, the chemical is called rhodopsin; in the cones, the chemicals are called colour pigments. To reduce the amount of reflection occurring, the retina is lined with the black pigment melanin which also plays a role in reducing harmful light radiation (Bianco, 2000).

When light hits the retina, a sequence of complex chemical reactions occurs. The result is the formation of a chemical – activated rhodopsin – that in turn creates various electrical impulses in the optic nerve (Bianco, 2000). The complete process is described as follows:

> *When light enters the eye, it comes in contact with the photosensitive chemical rhodopsin (also called visual purple). Rhodopsin is a mixture of a protein called scotopsin and 11-cis-retinal -- the latter is derived from vitamin A (which is why a lack of vitamin A causes vision problems). Rhodopsin decomposes when it is exposed to light because light causes a physical change in the 11-cis-retinal portion of the rhodopsin, changing it to all-trans retinal. This first reaction takes only a few trillionths of a second. The 11-cis-retinal is an angulated molecule, while all-trans retinal is a straight molecule. This makes the chemical unstable. Rhodopsin breaks down into several intermediate compounds, but eventually (in less than a second) forms metarhodopsin II (activated rhodopsin). This chemical causes electrical impulses that are transmitted to the brain and interpreted as light.*
>
> *Bianco (2000)*

These complex reactions are responsible for our vision. Each reaction produces a series of electrical impulses that in the brain are converted to colour and light sensations. The human capacity to discriminate colour isn't a process limited to the eye's components but also the result of processes in the cerebral cortex. This is to say that sight is only *complete* when the human brain receives impulses from the retina. The cerebral cortex is responsible for translating the electrochemical signals from the retina which ultimately identifies the images and their characteristics such as colour, form, shape, distance, size and orientation (Rosa, 2001).

2.2. Taxonomy of Eye Movements

Through a simple approach, some of the important structures that compose the eye and that make sight possible were described. However, when discussing vision, not only does the question *how do we see* arise, but also, what types of eye movements are our eyes capable of?

Before analysing a taxonomy of eye movements, it is necessary to understand what parts of our eye make eye movements possible.

There are six muscles – extraocular muscles – that coordinate the movement of the eyeball: the medial and lateral *recti* (responsible for sideways movement); the superior and inferior *recti* (responsible for vertical movement) and the superior and inferior obliques (responsible for twist). These muscles are visible in Figure 3.

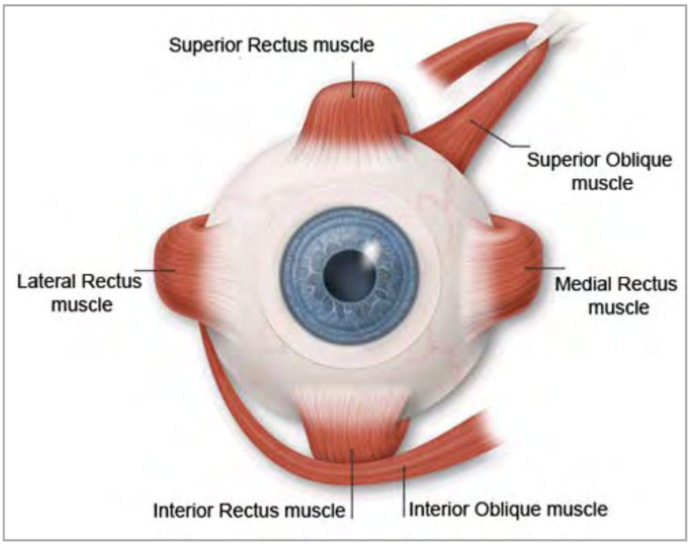

Figure 3 - Front view of Eye Muscles [retrieved from: (Anatomy)]

The six muscles' functions, simplified, are: Lateral rectus – to move the eye outward, away from the nose; Medial rectus – to move the eye inward, towards the nose; Superior rectus – to move the eye upward and slightly outward; Inferior rectus – to move the eye downward and slightly inward; Superior oblique – to move the eye inward and downward; Inferior oblique – to move the eye outward and upward (Eye Anatomy & Physiology, 2007). These pairs of muscles work together through the control of the brain. Furthermore, these pairs of muscles work in pairs such that, for example, if a person wanted their right eye to turn inward towards the nose, they would have to contract their internal rectus muscle while relaxing, with the same intensity, their external rectus muscle. If this contract-expand mechanism did not occur with the same intensity in both ways, the eye would move loosely in its socket (Hubel, 1995, pp. 28-29).

The eye's six muscles are, however, responsible for the eye's capability of realizing 5 different movements: saccadic movements, smooth pursuit movements, vergence, vestibular and fixations.

2.2.1. Saccadic movements

To explain the saccadic movement of the eyes, Guyton and Hall portray the following:

> *When a visual scene is moving continually before the eyes, such as when a person is riding in a car, the eyes fix on one highlight after another in the visual field, jumping from one to the next at a rate of two to three jumps per second. The jumps are called saccades, and the movements are called opticokinetic movements. (…) Also, the brain suppresses the visual image during saccades, so that the person is not conscious of the movements from point to point.*
>
> *(Guyton & Hall, 2006)*

From the explanation above, it is understandable that saccades are rapid eye movements. Saccades are both voluntary and reflexive and are used in repositioning the *fovea*[4] to a new location in the visual field. Saccadic movements last approximately 10 ms to 100 ms (0.01 to 0.1 seconds). When a target is moving, information related to the target's movement travels to the *superior colliculus*[5] in the brainstem, responsible for moving the eye in the short jumps termed saccades. The neuronal functions controlling saccades are still debated. Some believe that they are ballistic, that is, that saccade destinations are pre-programmed. Others consider them to be stereotyped, that is, saccadic movement patterns can be recalled repeatedly (Hubel, 1995, p. 42).

2.2.2. Smooth pursuit movements

If an object of interest is in movement, the eyes have the ability to remain fixed on that specific object. These movements are called *pursuit movements* or *smooth pursuits*. A complex mechanism is able to sense the movement of an object and develops a complementary course of movement for the person's eyes (Guyton & Hall, 2006, p. 647). The same authors exemplify the movement in the following manner:

> *If an object is moving up and down in a wavelike form at a rate of several times per second, the eyes at first may be unable to fixate on it. However, after a second or so, the eyes begin to jump by means of saccades in approximately the same wavelike pattern of movement as that of the object. Then, after another few seconds, the eyes develop progressively smoother movements and finally follow the wave movement almost exactly. This represents a high degree of automatic subconscious computational ability by the pursuit system for controlling eye movements.*
>
> *(Guyton & Hall, 2006)*

Furthermore, depending on the variability of the object's movement, the eye is capable of matching the object's velocity (Hubel, 1995, p. 46).

2.2.3. Vergence movements

Vergence eye movements are believed to be a later evolved eye movement. Contrary to the other eye movements, vergence movements are disjunctive, that is, they move in opposite directions. When looking from an object placed further away towards a closer placed one, the eyes will converge (i.e., rotate towards the nose); moving from a closely placed object to one further away, the eyes will diverge (i.e., rotate towards the temples). Also, vergence movements are quite slow when compared to the others, with durations of 1 second or longer. There are two main reasons for the occurrence of vergence movements: retinal image blur and retinal disparity. If an image is somewhat distorted, this is because it is too close or too far away. This will cause the eye to look for a clearer vision resulting in a change in vergence as well as in the pupil's size. Finally, if an object is casting its image unevenly on the retina, vergence eye movements are used to realign the lines of sight to attain singular binocular vision (Wong, 2007, p. 82).

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[4] Fovea: area of the retina where the quantity of photoreceptor cells is the greatest (160,000/mm2); the fovea is responsible for sharp vision. [Consulted: please consult (Purves, Sadava, Gordon, & Craig, 2002) in References section]

[5] Superior Colliculus: it is believed to play a role in integrating sensory information (visual, auditory, somatosensory) into motor signals that help orient the head toward various stimuli. [Retrieved from: http://www.skidmore.edu/~hfoley/Perc3.htm; January 3, 2009]

2.2.4. Vestibular movements

The vestibular movement, also known as the vestibular-ocular reflex (VOR), is a movement capable of maintaining the retinal image while the head is in movement. The mentioned is possible through the counter-rotation of the eyes at the same velocity the head moves in the opposite direction. As the head moves, information related to its movement is sent from the vestibular sensors located in the inner ear to VOR circuitry present in the brainstem which then calculates the correct eye velocity. Therefore, the function of the VOR is to create a direction for the eye that balances changes in the head's position and orientation. Additionally, because of the reflexes' vestibular origin, it is able to function not only in light but also in darkness (Wong, 2007, p. 22).

2.2.5. Fixations

Fixations are possibly the most important of the eye movements such that they are responsible for the ability to fix our gaze upon objects in the visual field. The fixation eye movement is controlled by two neuronal mechanisms; the first, the *voluntary fixation mechanism*, allows humans to voluntarily find the object on which they want to fix their vision; the second, the *involuntary fixation mechanism*, holds the eye on the object once it has been found (Guyton & Hall, 2006, p. 645). Fixations are identified by various small eye movements: *microtremors, microsaccades* and *microdrifts*, the last being responsible for preventing the fading of stable images (Wong, 2007, p. 18). 90% of a person's viewing time is through fixations which last from 150 ms to 600 ms (0.15 to 0.6 seconds) (Hubel, 1995, pp. 46-47).

These five eye movements are a result of the eye's remarkable capabilities. Furthermore, with the advances in technology, these eye movements are now capable of being registered and analysed using eye tracking systems; a technology that will be explored in the following section of this dissertation.

3. Eye Tracking Systems

A German proverb states that *it is better to trust the eyes rather than the ears* (Book of Famous Quotes, 2009). Possibly with this idea in mind, during the past decades the scientific community has witnessed interesting advances in the field of eye tracking, a technology that allows researchers to study and analyse eye movements.

3.1. Eye tracking Techniques

The eye tracker is presently the most common of the devices used for determining and measuring eye movement. Two types of eye movement techniques are generally considered: first, the technique that measures the eye's position relative to the head and secondly, the technique that measures the orientation of the eye in space, also known as the *point of regard (POR)* (Young & Sheena, 1975 apud. (Duchowski, 2007, p. 51)). The second technique is commonly used to identify items in a visual scene such as traditional web interfaces whereas the most widely applied technology for this measurement is the video-based corneal reflection eye tracker (Duchowski, 2007, p. 51).

In *Eye Tracking Methodology*, Duchowski (2007) presents four extensive categories of eye movement measurements involving the use or measurement of: Electro-OculoGraphy (EOG), sclera contact lens/search coil, Photo-OculoGraphy (POG) or Video-OculoGraphy (VOG) and video-based combined pupil/corneal reflection which will be discussed in the following section.

3.1.1. Electro-OculoGraphy

The Electro-OculoGraphy, 40 years ago, was the most commonly applied eye movement monitoring method. It consists of the measurement of the skin's electric potential differences based on electrodes placed around the eye as seen in Figure 4.

The EOG measures the eye's movements relative to the head's position. For that reason, the EOG technique isn't the most appropriate for point of regard measurement (Duchowski, 2007, p. 52). THE EOG's non invasive and easy to mount characteristics are just two of this technique's advantages. Equally, the technique does not pose any problems for people that use glasses. Furthermore, it can be easily used while a person freely moves his or her head and has his or her eyes closed. However, the amount of light present in the environment must be kept constant due to its influence on the corneo-retinal potential charges (Deuschl & Eisen, 1999, p. 224).

Figure 4 - Example of an EOG eye movement measurement [retrieved from: (Duchowski, 2007, p. 52)]

3.1.2. Scleral Contact Lens/Search Coil

The Scleral Contact Lens/Search Coil is one of the most precise eye measurement methods. It consists of attaching a mechanical or optical object onto a contact lens which is then worn on the eye. The contact must be large, covering both the cornea and the sclera. Were it to cover only the cornea, it would eventually slip of the eye. The sclera contact lens/search coil technique has evolved over the years and now consists of a modern contact lens on which a mounting stalk is attached. Various devices have been affixed to the stalk such as reflecting phosphors, line diagrams and wire coals. The sclera contact lens/search coil method is both intrusive and uncomfortable for the user and not suitable for point of regard measurement (Duchowski, 2007, pp. 52-53).

3.1.3. Photo-OculoGraphy or Video-OculoGraphy

Both these techniques group a large variety of eye movement recording techniques that involve the measurement of various eye features under rotation/translation. The mentioned techniques are grouped together because they normally don't grant point of regard measurement. The measurement of eye movements offered by these techniques is not always automatic and therefore could require visual inspection of the recorded eye movements which in turn is wearisome and subject to error (Duchowski, 2007, pp. 53-54).

3.1.4. Video-Based Combined Pupil/Corneal Reflection

The previously mentioned techniques, despite useful for measuring eye movement, do not grant point of regard measurement. To provide POR measurement either the head must be fixed so that the eye's position relative to the head and point of regard coincide, or multiple ocular features must be measured in order to disambiguate head movement from eye rotation. Two of these features are the corneal reflection (usually by means of an infra-red light source) and the pupil center (Duchowski, 2007, p. 54) as seen in Figure 5.

Video-based eye trackers use cameras and image processing hardware to calculate the point of regard in *real-time*. The measurement may be done through the use of a table mounted eye tracker or worn on the head.

Figure 5 - Example of a Corneal Reflection [retrieved from: (Duchowski, 2007, p. 55)]

Both devices of measurement are similar in optical terms and are systems that are more frequently being used as they are useful for measuring eye movements in interactive systems. The eye's corneal reflection of the light source is measured relative to the location of the pupil's center. These reflections are also known as *Purkinje reflections* or *Purkinje images*. When the light hits the eye, four Purkinje reflections are formed. Video-based eye trackers are capable of locating the first Purkinje image (Duchowski, 2007, pp. 54-56).

Separating eye movements from head movements requires two points of reference. As Duchowski sates, the positional difference between the pupil center and corneal reflection changes with pure eye rotation, but remains relatively constant with minor head movements (Duchowski, 2007, p. 57). However, this difference remains constant with slight head movements. Since the source of the light is normally placed at a fixed position relative to the eye, the Purkinje image is relatively stable while eyeball and pupil rotate in its orbit (Duchowski, 2007, p. 57). Some eye trackers also measure the fourth Purkinje image. By measuring the first and fourth Purkinje image, dual-Purkinje image eye trackers are able to separate translational and rotational eye movements. This sums up a quick overview over some of the eye tracking techniques available for measuring eye movement. The question that now follows is in what way these techniques have been applied in usability research as well as what benefits and limitations are natural to the technology.

A study dated back to 1947, led by Paul Fitts and his colleagues, is the first example of the use of an eye tracking application in the field of usability engineering. The use of motion cameras was applied to study pilots' eye movements as they used cockpit controls and instruments to land a plane (Jacob & Karn, 2003). Since then, many advances in the technology have taken place. Still, many questions and problems have yet to be answered.

3.2. Limitations of Eye Tracking

In Jacob and Karn's (2003) research, quotes from various researchers such as Crowe & Narayanan (2000), and Redline & Lankford (2001) are presented. The common idea that binds them all is one that states that eye tracking is a *promising* technique in the field of usability engineering. It may be considered promising because it is a valuable technique but simultaneously, has its flaws. For that reason it has not made the complete jump from promising to *effective.* As Jacob and Karn (2003) state, there are three possible reasons for the technology's *slow start* in usability research: *technical problems with eye tracking in usability studies*, *labour-intensive data extraction* and *difficulties in data interpretation*. These three questions will be looked at in the following sections.

3.2.1. Technical Problems in Usability Studies

When more than 50 years ago, Paul Fitts and colleagues developed the first eye tracking application (Fitts et al., (1950) apud Jacob & Karn (2003)), the technology at the time must have necessarily been revolutionary and complex. However, these days, eye trackers are easier to operate.

Commercially available eye tracking systems that are commonly used for laboratory studies, as mentioned before, focus on the measurement of the point of regard. Vendors and manufactures usually provide software to assist in the setup and calibration process. The video based technique along with the simple calibration process make eye tracking systems not only easy to use but also trustworthy methods of analysis.

Nevertheless, Jacob and Karn (2003) defend the need to dissipate, as much as possible, the *relationship* between the eye tracking device and the participant. This could possibly be the biggest barrier to the use of eye tracking in more usability studies. Despite the existence of two valid options for eye movement analysis, both impose some limitations in terms of comfort and movement restrictions. Researchers may choose from using a table mounted eye tracking system that limits a user's body movement or using a head mounted system that is fixed to the user's head in an uncomfortable fashion. In terms of mobility, recent advances have been made in the development of portable eye trackers that make traditionally difficult analysis of portable equipment (such as cell phones and PDAs) through eye tracking easier to execute. However, despite the evolution verified over the past years, many are still reluctant to use this technology in usability research.

3.2.2. Data Extraction Problems

Commonly used eye trackers produce information that represents the user's visual orientation. Typically, the system will present results with a vertical and horizontal coordinate. Despite what might seem simple, depending on the sample rate used as well as the duration of each session, the quantity of data might quickly become large (Jacob & Karn, 2003, p. 579). Therefore, it is a good strategy to distinguish early on in the analysis the saccades and the fixations, two collections of data based on eye movements. Normally, software will be able to filter these two types of data, simplifying the workload.

However, due to the dynamic nature of common user interfaces, studying eye movements, namely fixations, can be difficult. In today's interfaces, animations, pop-ups and dynamic text are common and therefore make the mission to filter fixations harder than with a static stimulus.

Another difficulty with data extraction can be placed upon the user's head or body movement. In this case, the use of head-tracking systems along with eye tracking systems can diminish this problem (Jacob & Karn, 2003, p. 580).

Despite these advances, in some cases, researchers have no choice but to do manual work and proceed to a manual frame-by-frame coding of video recordings and identification of fixation points, similar to what was done in El-Nasr & Yan's project - Visual Attention in 3D Video Games (2006) - as will be discussed later on in the Video Game Evaluation section.

3.2.3. Problems with Data Interpretation

As Jacob and Karn (2003) point out, if the previous two *limitations* do not pose a threat to the researcher, the question of interpreting the data is still a problematic barrier for the evolution of the eye tracking technique. The question that might be asked is: *How does the usability researcher relate fixation patterns to task-related cognitive activity?* (Jacob & Karn, 2003, p. 580).

Interpreting data can be done using either the top down-method (based on either the cognitive theory or design hypothesis) or the bottom-up method (based on data observation without eye movement/cognitive activity relations). To exemplify, Jacob and Karn (2003) present the following:

> *Top-down based on a cognitive theory: Longer fixations on a control element in the interface reflect a participant's difficulty interpreting the proper use of that control.*
>
> *Top-down based on a design hypothesis: People will look at a banner advertisement on a web page more frequently if we place it lower on the page.*
>
> *Bottom-up: Participants are taking much longer than anticipated making selections on this screen. We wonder where they are looking.*

The top-down method based on cognitive theory may seem the most appealing but, in many cases researches don't have a well-founded theory or hypothesis to *drive* the analysis (Jacob & Karn, 2003, p. 580). If that is the case, the mentioned authors suggest applying a data-driven search for fixation patterns.

To be able to interpret eye tracking data, the researcher must select variables or metrics to analyse using the data acquired. Jacob and Karn (2003) present some of the most used eye tracking metrics used by researchers: fixations, gaze durations, area of interest and scan path.

Fixations, as mentioned in the human visual system section, are relatively stable eye movements. Gaze Durations are the cumulative duration and average spatial position of a series of successive fixations within an area of interest. Gaze durations normally include various fixations as well as small saccades between the fixations. As soon as the eye moves outside the area of interest, the gaze is terminated. The Area of Interest is an area in the visual environment that is of interest to the researchers and the focus of the study. The Scan Path is the spatial arrangement of a progression of fixations.

As Jacob and Karn (2003) point out, possibly the biggest hurdle for the use of eye tracking in usability studies is the eventual difficulty in relating eye tracking data with cognitive activity. Therefore, researchers that choose to use this method of evaluation in their studies must ask themselves: *"What aspects of eye position will help explain usability issues?"*

Despite some hesitations and difficulties in the affirmation of eye tracking as a valid usability measurement technique, many do believe in its benefits and potential. We will now look at some of the strengths associated to the use of eye tracking in usability research.

3.3. Strengths of Eye Tracking

Keith Karn (Karn, 2006) defends the use of eye tracking in studies of human-computer interaction where its benefits have been previously demonstrated. That is the case of visual search, learning, the visibility of product features and the analysis of certain tasks where other traditional usability testing methods have found a problem. With that in mind, Karn presents an extensive list of benefits associated to the use of eye tracking for usability evaluation (Karn, 2006).

In technological terms, the eye tracking technique is one that many people, researchers included, find interesting. Also, eye tracking is relatively inexpensive as well as useful for tracking what area of a larger *image* (whether it be static or dynamic) a user is looking at. Furthermore, video-based eye tracking equipment is becoming relatively inexpensive. Finally, tools that assist in the analysis of eye tracking data are becoming available and are better than existing previous solutions.

As mentioned above, eye tracking can be applied to areas where its benefits have the most impact. These are, as Karn (2006) lists: the deployment of visual attention during task-guided search or more general viewing; learning (changing of fixation patterns over time); evaluating efficiency of systems where visual-motor reaction time is crucial (e.g., systems used under emergency situations) and finally, in the analysis of tasks where traditional usability testing methods have indicated a problem that eye tracking might clarify (e.g., delays during product use that traditional think-aloud protocols do not elucidate).

More than studying a user’s reaction time, analyzing their visual search pattern can help understand the strategies that a user exercises when visualizing a stimulus. This can be applied in studies where it is necessary to understand a user’s search pattern over product features as well as in web pages, for example. Also, it can help in understanding what parts of an interface cause or have the most impact on a user.

As for the learning component, eye tracking can be used to understand in what ways novice users differ from expert users in terms of search patterns as well as how a certain user evolves in terms of his or her own search pattern.

Eye tracking can also be used for the evaluation of systems and their efficiency where visual-motor reaction time is important. Examples of these types of situations are aircraft landings, power plant emergencies and warfare, etc.

Finally, when traditional usability evaluation techniques encounter a problem with a product, eye tracking can be used to further clarify what the problem is. Of course this is only beneficial for some products due to the context limitations we’ve seen before.

There are, therefore, many questions to be answered when the desire to apply eye tracking to usability testing surfaces. In many cases, eye tracking technology is a good method to start evaluating a product or to complement an assessment having previously used another usability evaluation method. In other cases, eye tracking still presents some limitations and is not the most recommended method for evaluation. Whatever the case, it is up to the researcher to understand what he or she needs to be evaluated and whether or not his or her choice of methods can deliver the required and desired results.

4. Usability

In the previous section, usability as well as eye tracking as an evaluation method was discussed. Both these concepts will now be discussed more in depth.

4.1. What is usability?

There is no one correct definition for usability. However, many of the existing definitions converge to the idea that *usability measures the quality of a user's experience (through various aspects) when interacting with a product or a system*[6]. The notion of user experience, specifically game experience, will be further analysed in the *Evaluating Game Experience* section.

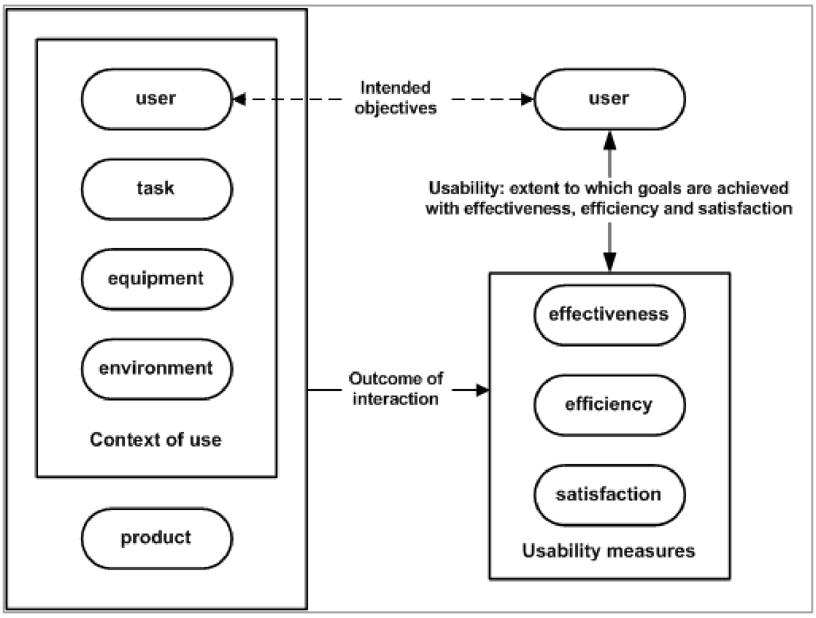


Figure 6 – Usability Framework [retrieved from: (ISO, 2009)]

[6] Website: http://www.usability.gov/basics/whatusa.html#whatdoes

The International Organization for Standardization (ISO) norm 9241-11 defines usability as *the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use*[7]. In this definition, there are three main concepts: effectiveness, efficiency and satisfaction. (1) Effectiveness refers to the user's ability to complete specific goals; (2) efficiency deals with a user's ability to accomplish tasks without difficulty; finally, (3) satisfaction refers to how much a user enjoys and accepts using a product. Furthermore, the concept *context of use* is important and encloses 4 variables: a user – the person that interacts with the product; the goal – a proposed objective; a task – the activities undertaken to achieve a goal and the product – the equipment (software, hardware or material) for which usability is to be assessed (ISO, 2009). The presented usability framework can be seen in Figure 6.

A second definition is Jakob Nielsen's[8] approach to the concept. He advances with a 5 component definition that focuses however, on web design and interface development. The 5 components are, as Nielsen (Nielsen, 2003) himself describes: learnability, efficiency, memorability, errors, and satisfaction. (1) Learnability refers to how easy it is for users to accomplish basic tasks the first time they encounter the design (i.e., the interface design); (2) efficiency refers to how quickly a user can accomplish a certain task once he has learned the design; (3) memorability relates to how easily a user can re-establish proficiency when users return to a design they haven't used after a certain period of time; (4) errors refers to the number of errors users commit, how severe they are and how easily they can recover from them; finally, (5) satisfaction relates to how pleasurable it is to use the design.

Rubin and Chisnell (Rubin & Chisnell, 2008, pp. 4-5) present a similar approach on the concept of usability. Their model consists of 6 attributes (as they call them): usefulness, efficiency, effectiveness, learnability, satisfaction, and accessibility. (1) Usefulness describes the extent to which a product allows a user to complete his or her objectives; (2) efficiency, similarly to what we've seen above, is measured by how quickly a user can complete his goal completely and accurately; (3) effectiveness refers to the degree in which a product performs how the user expects it to as well as how easy users can do what they want to with it; (4) learnability is related to effectiveness and refers to the user's ability to use, with a certain degree of competence, a product after a determined period of time; (5) satisfaction, much like in the previous definitions, refers to the user's personal opinions on the product; lastly, (6) accessibility which, according to the authors, is bonded with usability. However, accessibility focuses on how a product is made usable for users with disabilities. The question that follows nonetheless is: *what makes a product less usable?*

Rubin and Chisnell (Rubin & Chisnell, 2008, pp. 6-11) indicate five reasons why products are hard to use: product development focuses on the machine or system; the target audiences change and adapt; designing usable products is difficult; team specialists don't always work in integrated ways; design and implementation don't always match.

The first reason – product development – is related to the recurring problem that during the process of designing and developing a product, developers center their attention on the machine/system and not enough on the user. As the authors point out, since a product's end objective is to facilitate or improve user performance in some area, more attention should be paid to the user during product development.

[7] Website: http://www.upassoc.org/usability_resources/about_usability/definitions_of_usability.html [Consulted: January 5, 2009]

[8] Jakob Nielsen is a renowned usability consultant, holding a Ph.D. in Human-Computer Interaction from the Technical University of Denmark.

The second reason takes into account the target audience; an audience that is expanding every day. The original users of technology were basically experts in terms of technological knowledge while today's users may have much or little to none. Furthermore, many of these users don't have the patience to *play* with the product to get to know and adapt to it. Today's user wants at his or her disposal a tool they can use without worrying too much about it.

The third reason is related to usability. Despite the information available through various sources, the concept *usability* is still somewhat ambiguous even though many companies believe it to be "common sense". The truth is however, that designing a usable product is still a difficult task.

The fourth reason products are hard to use relates to problems that occur when a product is developed by various specialized teams. Although that isn't necessarily a problem, when teams don't communicate among each other and don't properly integrate each part of the product, problems will naturally occur.

Finally, just as technology has evolved, so has the design of products. Both the design and implementation process are being affected by the expansion of new-generation programming languages as well as the surfacing of new target audiences which makes it a bigger challenge to develop a product suitable for all.

Understanding what causes a product to be less usable is a useful step towards knowing how to make a product more functional. Rubin and Chisnell (Rubin & Chisnell, 2008, p. 12) suggest three ideas for making products more usable: an early focus on users and their tasks; evaluating and measuring product use; finally, iterated design. (1) An early contact between end-users and the product design team throughout the product's development is more important than just identifying the primary users of a product. Establishing a connection between these two parts will result in the development of a product that meets, in a more accurate manner, the needs of a user. (2) As for evaluating and measuring the product, both of these analyses should be done constantly throughout the development cycle with emphasis on the ease of learning as well as the ease of using the product. (3) Finally, iterative design and testing should be a process that accompanies a product's development cycle and not just the end moments. As the authors point out, *true iterative design allows one to "shape the product" through a process of design, test, redesign, and retest activities.* These 3 points are a small portion of a global picture – user-centered design (UCD) – a concept first introduced by Donald Norman in The Design of Everyday Things (Norman, 1998) which focussed on the design of products based on users' needs and with less concern for the product's aesthetics. Rubin & Chisnell define UCD as *representing the techniques, processes, methods, and procedures for designing usable products and systems, but just as important, it is the philosophy that places the user at the center of the process* (Rubin & Chisnell, 2008, p. 12).

What we can extract and add to this idea is that when a product or system is being developed, just as important as what technologically supports the product are the user's problems, concerns and experiences. These three factors should be just as prioritized as the technological backbone when preparing a product development cycle.

The previously stated is just a glimpse of how complex it is to design usability. Making a product or system usable for a vast group of users is not by any means a simple objective and requires much debate among the development team.

4.2. Evaluating usability

Just as important as knowing what attributes to follow when developing a usable product are the methods used to evaluate a product's usability once it has been completed. However, usability evaluation should not be considered the last phase of the product development cycle. The evaluation process should occur in parallel to the product's development. Nonetheless, it seems reasonable that intensive evaluation is not possible during the complete cycle. There are however, other techniques that can be applied and used (Dix, Finlay, Abowd, & Beale, 1998, p. 406).

Bearing in mind Dix et al.'s (1998, pp. 406-407) focus on Human-Computer Interaction, they affirm that evaluation has three main goals: assessing the extent of a system's functionality; assessing the effects of the interface on the user; and identifying any specific problems with the system. (1) In what concerns the system's functionality, it should be capable of meeting the user's needs as well as his or her expectations. (2) Evaluating a system in terms of interface means that the impact of the system's design on the user should be assessed. That is, the system's easiness of use and learnability as well as the user's attitude towards the system. Finally, (3) identifying specific problems with the system remits to identifying problems with a system that, in its context of use, caused unexpected errors, both in terms of functionality and design.

Many authors divide and categorize usability testing methods in different ways. Dix et al. (1998, pp. 405-435) present a hierarchical division where as Ben Shneiderman (1998, pp. 124-151) presents a more linear view on the subject. Despite this difference, both Dix et al. and Shneiderman discuss similar techniques and methods.

Dix et al. (1998, pp. 407-408) presents two styles of evaluation: laboratory studies and field studies. (1) Laboratory studies, as the name suggests, are studies conducted in the laboratory. Laboratories may be equipped with technology and conditions that make it a more beneficial environment. However, the *lack of context*, as the authors define it, may inhibit, for some users, a more natural evaluation. Nevertheless, the use of a laboratory study in some cases is the only option. (2) Field studies however, take the evaluator to the user's natural environment, a place where he or she feels more comfortable. Still, field observation presents many possible distractions which, on one hand can benefit the evaluation but on the other, can also sabotage it.

A further division in usability testing methods proposed by Dix et al. (1998, pp. 408-415) separates design evaluation from implementation evaluation.

Design evaluation focuses more on evaluating a product before mistakes are too costly as well as to, as the authors point out, *identify areas which are likely to cause difficulties because they violate known cognitive principles, or ignore accepted empirical results*. The *cognitive walkthrough* and the *heuristic evaluation* are just two of the methods presented. (1) The cognitive walkthrough's main focus, as suggested by the authors, is to verify how easy a system is to learn. In a cognitive walkthrough, an evaluator is presented a list of steps he or she must follow to complete a determined task. The second (2) method is the heuristic evaluation. A heuristic is *a guideline or general principal or rule of thumb that can guide a design decision or be used to critique a decision that has already been made* (Dix et al., 1998, p. 412). The concept of heuristic evaluation was introduced by Jakob Nielsen and Rolf Molich and refers to a method for organizing the assessment of a system using a set of heuristics. Normally, heuristic evaluation will be run by various evaluators that independently evaluate and analyse a system searching for potential usability problems. The list of heuristics used in heuristic evaluation is composed of 10 points as presented in the following table (Table 2).

1. **Visibility of system status:** The system should always keep users informed about what is going on, through appropriate feedback within reasonable time.

2. **Match between system and the real world**: The system should speak the users' language, with words, phrases and concepts familiar to the user, rather than system-oriented terms. Follow real-world conventions, making information appear in a natural and logical order.

3. **User control and freedom:** Users often choose system functions by mistake and will need a clearly marked "emergency exit" to leave the unwanted state without having to go through an extended dialogue. Support undo and redo.

4. **Consistency and standards:** Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform conventions.

5. **Error prevention:** Even better than good error messages is a careful design which prevents a problem from occurring in the first place. Either eliminate error-prone conditions or check for them and present users with a confirmation option before they commit to the action.

6. **Recognition rather than recall:** Minimize the user's memory load by making objects, actions, and options visible. The user should not have to remember information from one part of the dialogue to another. Instructions for use of the system should be visible or easily retrievable whenever appropriate.

7. **Flexibility and efficiency of use:** Accelerators -- unseen by the novice user -- may often speed up the interaction for the expert user such that the system can cater to both inexperienced and experienced users. Allow users to tailor frequent actions.

8. **Aesthetic and minimalist design:** Dialogues should not contain information which is irrelevant or rarely needed. Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility.

9. **Help users recognize, diagnose, and recover from errors:** Error messages should be expressed in plain language (no codes), precisely indicate the problem, and constructively suggest a solution.

10. **Help and documentation:** Even though it is better if the system can be used without documentation, it may be necessary to provide help and documentation. Any such information should be easy to search, focused on the user's task, list concrete steps to be carried out, and not be too large.

Table 2 - Ten Usability Heuristics

Despite this comprehensive list, as Dix et al. (1998, p. 414-415) point out; any problem an evaluator might encounter is a usability problem, even if it cannot be easily categorized in the presented list. The heuristics are simply a guideline to help evaluators find potential problems.

Taking a look at implementation evaluation, Dix et al. (1998, p. 415) present three possible methods: the empirical method: experimental evaluation; observational techniques and query techniques.

The empirical method is arguably one of the most potent methods for evaluating as it provides empirical evidence to sustain a proposed hypothesis as well as its potential use in the most diverse contexts. Any empirical study (or experiment) follows the same procedures: the evaluator chooses a hypothesis he or she wants to test and that can be determined by measurement of some attribute of subject behaviour; the evaluator then considers the experimental conditions which are influenced by the values of determined variables. Despite this simplistic view of the empirical method, factors such as the experiment subjects, the variables chosen to test and manipulate as well as the hypothesis tested are crucial.

Choosing the correct subjects is one of the most important parts of an experimental evaluation. The subjects chosen to participate in any study should share, as much as possible, the same characteristics (e.g. age, degree of education, etc.) of the expected end users. If possible, the experiments subjects should be equivalent to the expected end user population. In terms of number of participants, the number of subjects chosen should always be in sufficient number to have a representative value of the general population. Dix et al. (1998, p. 416) suggest that for controlled experiments, 10 participants should be the minimum number of subjects used in a study. Secondly, the choice of the variables studied is also important. The purpose of experiments is to manipulate and measure variables in predetermined conditions so that hypothesis may be tested. There are two types of variables: *independent variables* which are manipulated and *dependant variables* which are measured. Independent variables refer to characteristics of an experiment which are controlled to generate a series of different conditions for comparison. Furthermore, more complex experiments are known to study more than one independent variable. On the other hand, dependent variables are those that can be measured; additionally, they must be affected by the independent variable(s) and unaffected, as much as possible, by other external factors. Some common dependent variables that are measured through experimentation are the *time* that it takes to complete a task as well as the *number of errors* a user makes. Thirdly, there is the hypothesis which is a prediction for the outcome of the experiment. The hypothesis is proposed taking into account the variables and stating that changes in the independent variable(s) will affect the dependent variable. The experiment's final goal is to prove that the hypothesis is correct.

A second method of evaluation are the observational techniques which Dix et al. (1998, p. 427-431) divide into *think aloud process*, the *protocol analysis*, the *automatic protocol analysis* and *post task walkthroughs*. However, for this section, only the think aloud process and the post task walkthroughs will be discussed. The think aloud protocol is a process used to observe users interacting with a system while completing a series of tasks or in a second variant, observing users go about their normal day. While completing their task(s), users are asked to "think aloud", that is, describe what they feel is happening, why they're doing or what they are trying to do. Despite its simplistic nature and usefulness for encountering problems, depending on the task being performed, the results can eventually be subjective and selective. Secondly, the post-task walkthrough consists of reproducing and analysing with the subject what he or she did during a task for better understanding. This is to say that in many cases, data obtained through direct observation is not complete or fully understandable. If that is the case, the experimenter will want to go back with the user to discuss what he or she was doing or saying (if having used the think aloud process). This may be done at different times of the evaluation: right after a certain task or later on in the experiment.

Finally, query techniques are also used for evaluation (Dix et. al, 1998, p. 431-435). Despite being less controlled by the analyst, they may provide useful information regarding the user's opinion of the product or system. Positively, they are simple and low cost methods of evaluation. However, they do return very subjective results which may be difficult to understand. Query techniques are divided into two main categories: *interviews* and *questionnaires* (Dix et. al, 1998, p. 432). (1) Interviews are a successful way to obtain information from users related to their preferences, attitudes and impressions as well as uncovering problems the analyst had not predicted. For full effect, interviews should be planned in advance so that consistency is maintained. Nonetheless, this does not mean that an interview can't be open and approach other information not previously thought of. (2) There are various types of questionnaires, each with a different purpose. Questionnaires take less time to be completed and focus on more specific questions. However, the elaboration of a questionnaire requires previous thought on the type of information the analyst expects to obtain.

As mentioned earlier, Shneiderman (1998) also presents a grouping of usability evaluation methods. His list is composed of *expert reviews, usability testing and laboratories, surveys, acceptance tests, evaluation during active use, controlled psychologically oriented experiments, practitioner's summary* and *researcher's agenda.* For the present study, only the first 5 methods Ben Shneiderman indicates in his work will be discussed.

The expert reviews method presented by Shneiderman (1998, p. 125-127) encloses various methods: heuristic evaluation, guidelines review, consistency inspection, cognitive walkthroughs and formal usability inspections. We've seen above the characterization of some of these methods. Nonetheless, it should be mentioned that Shneiderman's heuristic evaluation touches some different aspects than the one Dix et al. (1998, pp. 412-414) referred to. Shneiderman's heuristics are composed of what he denominates *the eight golden rules* (Shneiderman, 1998, pp. 74-75).

Usability testing in laboratory (Shneiderman, 1998, pp. 127-132), as the name suggests, refers to the testing in a laboratory environment. As we've seen with Dix et al. (1998, p. 407), testing in laboratories offers controlled conditions and the possibility of obtaining more concrete answers to problems. The usability testing laboratories discussed by Shneiderman are those that staff people with knowledge in the area of usability testing and run tests like the one's discussed earlier (e.g. think aloud process).

The survey method (Shneiderman, 1998, p. 132-135), similarly to Dix et al.'s (1998, pp. 432-435) questionnaires seek to obtain user opinions regarding the use and functionality of a system or product.

Acceptance tests (Shneiderman, 1998, p. 135) can be described as a list of pre-requisites that a product must meet or that a user must be able to do. If this is not the case, the system or product must be revised until the criteria established is met.

Evaluating during active use (Shneiderman, 1998, p. 145) refers to the evaluation of a system after it is in use. Obtaining feedback through interviews and focus-group discussions, continuous user-performance data logging, online or telephone consultants, online suggestion box, online bulletin board or newsgroups as well as user newsletters are several suggestions that Shneiderman mentions.

Due to validity and usefulness of these techniques, namely the think-aloud protocol and the post task walkthroughs as referred to by Dix et al. (1998) as well as the surveys technique presented by Shneiderman (1998), these will be taken into consideration for use in the case study this project will contain.

We've seen from this short characterization some of the usability evaluation methods used for product or system assessment. However, many of these techniques were thought for particular systems and products like websites.

Associating video games and usability is a complex problem. Traditionally, they are two concepts with little correlation despite the fact that games, being themselves a product, must be usable. However, as we will see in the following section, among the video game development sphere, understanding the concept of usability is a difficult task.

4.3. Game Usability

Video games and usability are two concepts that could be easily interconnected. However, as we will see further on in this section, they are not easily matched. In Melissa Federoff's (Federoff, 2002) study, she discovers that even for people in the video game industry, the concept of game usability is unused or even unknown.

This however, does not sound as strange as it seems. After all, video games are more of a product devoted to entertain and not so much a tool to facilitate a user's daily tasks, as one of Federoff's (Federoff, 2002) study participants claimed.

This *problem*, nevertheless, has not passed unanswered among HCI research and studies. One of the first attempts to approach game usability was by the hand of Thomas Malone in 1980 (Malone, 1980). More recently, Chuck Clanton (Clanton, 1998) divided some of the core game usability issues into three categories: *game interface*, *game mechanics* and *game play*. The game interface (or *user interface* as he also suggests) refers to the visual and motor part of a game: how the controller works or what instruments and elements are displayed on the screen, for example. The game mechanics category remits to a game world's physics. That is, what abilities our characters have, the dynamics of a certain game element or object. These are developed through a combination of animation and programming (Federoff, 2002, p. 11). Finally, the game play refers to the process through which the player accomplishes his goal. Federoff (2002, pp. 11-12) goes a bit further in the elaboration of the 3 categories mentioned. Federoff describes the game interface as the elements that are used to actually control a video game whether it is a keyboard, a video game controller, a joystick or a mouse. Furthermore, the game interface is the visual representation of the various actions the player executes in a game: moving through the game, starting the game, exiting the game, etc. Secondly, the game mechanics are further described as the ways the player is able to move in the video game (e.g. walking, running). The game mechanics can be further divided into 3 parts: animation, programming and level design. The game animators build the referred movements, the game programmers elaborate the code and implement them and the game level designers build the scenarios and levels in which they take place. The conjunction of these three processes results in the game mechanics. Finally, the game play refers to the challenges and problems a player must overcome to win the video game. Additionally, all three aspects mentioned are dependant of the video game genre to which they are associated.

In Melissa Federoff's (2002, pp. 12-13) work, she recognizes that the question of usability in both video games and other products or systems is always dependent of the context in which it is inserted. That said, as we will see further sections, she was able to associate usability questions traditionally connected to other products with video games, developing herself a list of game design heuristics for usability evaluation.

Although heuristics, such as the ones Nielsen proposed, are normally projected for evaluating product interfaces and design, a similar application of heuristics is useful for video game development and evaluation. Furthermore, if we were to consider that a *usable* game is one that provides a user with entertainment and satisfaction, then game heuristics should cover design aspects that guarantee this satisfaction (Federoff, 2002, pp. 15-16).

Pinelle, Wong and Stach (Pinelle, Wong, & Stach, 2008) approach the usability question in similar terms. Considering that video games are products that require permanent interaction, usability is a significant problem in the video game industry. Their work, much like Melissa Federoff's (2002), is an attempt to counter the lack of methods to evaluate the usability of video games, specifically, the game interface. These authors' approach to game usability is to define it as *the degree to which a player is able to learn, control,* *and understand a game* (Pinelle, Wong, & Stach, 2008). Also, they present the argument that despite usability issues being common between both video games and other products, video games have the particularity of presenting usability questions that are not common in other products. An example of this is the fact that contrary to *regular* products, video games do strive to create problems through user errors. These errors are *built-in* to create a more challenging and simultaneously enjoyable game but also, as they describe, force the users to develop skills so that in-game objectives are completed.

Additionally, Desurvire, Caplan & Toth (Desurvire, Caplan, & Toth, 2004) indicate, in their approach to game usability, that when evoking video games and playability, one cannot limit themselves to the evaluation of the usability of the game interface. They defend the need to assess other video game properties such as game play, story, mechanics and usability; properties that will be analysed further on, in the *Video Game Evaluation* section.

Despite the fact many authors and researchers support the use of a method such as an adapted heuristic evaluation for evaluating the usability of games; others critique the use of traditional evaluation methods for the assessment of products and systems in general.

Cockton and Woolrych (Cockton & Woolrych, 2002) defend that so-called *discount methods* (heuristic evaluation included) aren't safe and that they can and should be improved. They characterize these methods as ones that cut corners and that are used in the hope that using some usability method is better than having used no method at all. Furthermore, *discount methods* are defined as ones that trim down on evaluation costs by cutting down on the resources that are essential for evaluation: time, facilities, cash and skill. Cockton and Woolrych go to the limit of criticizing these methods in the following manner:

> *Our research has led us to the conclusion that discount methods may be so error-prone that they discredit usability practitioners, and should be cleared off the HCI store's shelves.*
>
> *Cockton and Woolrych (2002)*

The authors mentioned present, nonetheless, suggestions for improving the methods they criticize but believe will remain used in the field of HCI. Among others, they emphasize that all HCI methods must be improved such that *discount* methods become more effective and other methods more practical. Another suggestion concerns the number of participants used. Using a mere handful of participants is a wrong approach in usability testing. Often, the cost difference between using 5 or 10 participants is minimal and ends up being a barrier in the evaluation procedure. Finally, they do recognize however, that these methods are useful as training devices. That is, they are useful for understanding that there are problems that require true user testing. Additionally, they acknowledge the existing differences between various types of products and that in some contexts, errors arising from the use of *discount* methods have greater impacts on some products than they do on others.

We've seen in this part of the Usability section some of the concepts and methods used traditionally for evaluating usability in products and systems. We've also seen that traditional techniques are being proposed as game usability evaluation methods. However, a video game cannot be reduced to its usability component nor its interface, mechanics and play (Clanton, 1998). In fact, video games deliver a different experience than the one received through using a normal product. It is that experience that will be analysed next.

4.4. Evaluating Game Experience

Nacke and Lindley's (Nacke & Lindley, 2008) work approaches video game evaluation through a different perspective: the game experience. In fact, playing a game, contrary to using a product, offers a different experience on many levels. Game players describe a series of experiences that are felt while playing video games: flow, immersion, boredom, excitement, challenge and fun. To explain how these series of experiences are felt during gameplay, Nacke and Lindley studied various psychophysiological elements. Intimately related to game experience are the player's emotions that influence a player's cognitive decisions while engaged in a game. According to the author's, existing psychophysiological research suggests that some of a human's emotional states can be quantitatively analysed through the study of physiological responses.

In their study, Nacke and Lindley analyse several responses such as the Facial Electromyography (EMG), the Galvanic Skin Response (GSR), Electrocardiography (ECG) and finally, Electroencephalography (EEG). None of these measurements can singly be used to evaluate a user's experience. However, correlating all of these can help in understanding the meaning of their patterns.

The facial EMG is a measurement of the electrical activity that is involved in the face's muscle contractions. Through facial muscle activation, the EMG supplies information (even if not clearly visible) on a person's emotional expression. Emotions considered as positive are a result of great amounts of activity at the cheek muscle (*zygomaticus major*) and the periocular muscle (*orbicularis oculi*) regions whereas high activity at the brow muscle (corrugators supercilli) are the result of negative emotions. Emotional perceptions such as happiness, joy, depression and anger are the result of different ratios of valance and arousal (Lang, 1995 apud Nacke & Lindley, 2008). The galvanic skin response allows for measuring a human's arousal state. The GSR is intimately related to the production of sweat by the eccrine sweat glands. Measuring both the GSR and facial EMG, interpretable data of a player's emotional state is achievable.

These authors' study, which composed of participants playing sequences of *Half Life 2* while measuring the responses mentioned above, concluded that physiological responses can be an indicator of psychological states of gameplay experience through the correlation of these with subjective testimonies.

Another similar approach towards the analysis and understanding of game experience is that of authors IJsselsteijn et al. (IJsselsteijn, et al., 2008). Similarly to the work presented above, these authors' study resulted in the Game Experience Questionnaire (GEQ) which studies various aspects of a player's game experience: Sensory and Imaginative Immersion, Tension, Competence, Flow, Negative Affect, Positive Affect, and Challenge. The GEQ is just a small part of a greater project in game experience research: FUGA: Fun of Gaming[9].

To truly understand what a video game is we must understand one of its core components: its interactive nature and the game player, the reason for which a game exists. After all, *there is no game without a player* (Ermi & Mäyrä, 2005).

The game experience, although unique in its nature, does share common traits with other types of experiences. The game experience can be defined, in a similar manner to those we've previously seen, as the ensemble of actions, feelings, sensations and thoughts lived by the player while interacting with a video game (Ermi & Mäyrä, 2005). Ermi and Mäyrä describe game experience in the following manner:

[9] FUGA: Fun of Gaming. [Project website: http://project.hkkk.fi/fuga/]

> *(...) it is not a property or a direct cause of certain elements of a game but something that emerges in a unique interaction process between the game and the player.*
>
> *Ermi & Mäyrä (2005)*

The game play experience is a personal experience such that, a player builds the experience while bringing into it parts of his or her life whether they be other lived experiences, knowledge from other areas or their desires. The agglomeration of these variables reflects on the manner in which the player interacts with the video game and lives out his or her game experience. A factor that intimately plays a role in gameplay experience is context. This is to say that different scenarios produce different types of sensations and feelings for the same video game. Furthermore, players search for a game experience that can only be truly achieved by engaging in game play. To exemplify, the experience of war, racing at high speeds, undercover missions are, for some, only possible through playing video games. To finalize, it must be understood that the game experience cannot be felt through passive participation with the video game. The player must seek full interaction with the game and be as active a participant as possible. When a player can successfully engage him or herself in a game, unique game experiences are thinkable as well as achievable.

5. Video Games

Certain aspects of video games have been briefly analysed in previous sections. In the following sub-sections other elements of video games relevant to this study will be looked into.

5.1. Video Game Genres & Taxonomies

Mark Wolf, in The Medium of the Video Game (Wolf, 2000), cites Ed Buscombe's essay *The Idea of Genre in the American Cinema*, which lists three areas in which genre elements may appear in film. Buscombe goes on to say, "*While the ideas of iconography and theme may be appropriate tools for analyzing Hollywood films as well as many video games, another area, interactivity, is an essential part of every game's structure and a more appropriate way of examining and defining video game genres"* (Buscombe, 1980 apud Wolf, 2000). What can be understood from Buscombe's statement is that the concept of interactivity is one that can be used to distinguish one type of game from another. Therefore, if between two games the interaction process is sufficiently distinct, quite possibly they are of two different types of video game genres.

Several years earlier, however, Chris Crawford (Crawford, 1982), one of the world's most notable computer game designers, defined in his *The Art of Computer Game Design*, a taxonomy to classify games. Crawford points out an interesting view on the categorization of video game genres suggesting that there is no correct taxonomy:

> *A taxonomy is only a way of organizing a large number of related objects. (…) The field [video games] is too young, the sample too small, for whatever organizing principles there may be to have asserted themselves. (…) Without a wide array of games there is little opportunity to choose between games (…) it is therefore impossible for us to devise a single, absolute taxonomy. Many taxonomies are admissible. Indeed, attempting to construct several alternative taxonomies is a useful way to examine the common traits of computer games.*
>
> *Chris Crawford (1982)*

It must be understood that Crawford's ideas were suggested in 1982, a time when games were only beginning to prosper. Since then, the industry has grown progressively and the possibility of organizing video games by genre is now as useful as ever.

With that in mind, Crawford's taxonomy was a division of computer games into two major categories, *Skill-and-Action Games* and *Strategy Games*, where each of these had a few of their own sub-categories.

The Skill-and-Action genre is divided into Combat Games, Maze Games, Sports Games, Paddle Games, Race Games and Miscellaneous Games. As for the Strategy Games category, Crawford includes Adventures, D&D Games, War games, Games of Chance, Educational and Children's Games as well as Interpersonal Games. Crawford considers that the main factor that divides one main category from another is the use of motor skills. While Skill-and-Action games use motor skills, Strategy games do not. Considering the year (1982) in which this taxonomy was proposed, as well as the games and video consoles being sold or even available, this taxonomy while being incomplete for the variety today, was sufficient for the assortment present at the time.

Returning to Wolf, he lists 42 different types of video game genres that *take into consideration the dominant characteristics of the interactive experience and the game's goals and objectives as well as the nature of the game's player-character and player controls* (Wolf, 2000).

Wolf's (2000) 42 genre *pitch* represents a broader look at the video game genres available, without great concern for categorizing similar genres as Crawford did. However, Wolf does indicate relations that exist between the various genres he presents. He indicates genres such as board games, card games, pencil and paper games as well as table-top games. Alongside these, he also indicates the adaptation genre. Wolf's definition of the Adaptation genre, "*games based on activities adapted from another medium or gaming activity (…)*" suggests that the genres mentioned earlier (board, card, pencil and paper, table top) could very well be subcategories of the adaptation genre. In addition to these, Wolf presents genres not mentioned before such as demo, diagnostic, rhythm & dance and utility. Furthermore, Wolf specifies other genres that have not yet been mentioned but, despite their singularity, are in many ways connected. Examples of these are, on one hand, the capturing, catching, chasing and the collecting genres and on the other, the dodging, escape, maze and obstacle course genres. As observed before, to the author, each of these genres is unique and there are many games that are categorized under the genre. However, their descriptions do indicate proximity between them. The first selection, as their names suggest, involves the searching and grouping of objects whereas the second selection reverts to avoiding objects as well discovering the correct path to accomplish an objective.

A more recent view on video game genres is that of Rollings and Adams (Rollings & Adams, 2003, p. 287). They present the following video game genres: action games, strategy games, role-playing games, sports games, vehicle simulations, construction and management simulations, adventure games, artificial life, puzzle games and online games. The online video game genre is one that hadn't been mentioned by either Crawford or Wolf. This could in part be due to the fact that both authors presented their ideas before online video games expanded drastically. Furthermore, some more recent authors may not even consider it a genre because in fact, it is more a technology then a game genre (Rollings & Adams, 2003, p. 489).

This brief introduction is just a sample of two of the taxonomies used to categorize video games. Just as Crawford suggested, there are no right or wrong taxonomies. Bearing that in mind, there are many existing taxonomies that share similarities between the two presented or are very different. One way or the other, any written taxonomy is the result of the author's interpretation of video games on one or various levels and his or her grouping of games considering such elements.

5.2. Video game genre analysis

We've just looked at some of the existing video game typologies. One of the most successful of the genres mentioned, and the genre chosen for the video game used in the case study, is the *First-person Shooter* Game (FPS)

5.2.1. First-person Shooter Games

As we've seen before there are many ways to classify video game genres. Rollings and Adams (2003) group FPS game into the bigger category of Shooting Games which in turn is a sub-category of Action Games.

One of the most distinguishable characteristics of Shooter games is their direction for violence as a main game mechanic. However, this doesn't imply (even though the genre name suggests it) that Shooter games involve constant shooting. They do, nevertheless, normally involve an avatar and the use of some weapon, whether it is a gun or something of the kind. Furthermore, the presence of enemies is a constant element in shooter games.

In their work, Rollings and Adams (2003) divide Shooter Games into first-person shooters and 2D shooters (e.g. Commando, Gauntlet Legends, Space Invaders and Centipede; 2D games as mentioned by the authors).

The exemplified games, in their original versions, we're all 2D games due to the fact that the idea of 3D environments and graphics was still a concept that had not yet been idealized. For this reason, and contrary to what in some cases is seen today, the main focus of these 2D games was extracting as much as possible from gameplay.

Figure 7 - Screenshot from the 1985 Arcade Game Gauntlet [retrieved from: http://www.virginmedia.com/images/gauntlet.jpg]

Gauntlet (see Figure 7), originally an arcade game from 1985, was one of the first games that introduced the concept of cooperative multiplayer. Furthermore, it introduced some game elements that were used in later games (Rollings & Adams, 2003, p. 292).

Robotron: 2084, an arcade game from 1982, consisted of defending a human family from destruction. In Robotron: 2084, the player could kill, using a second joystick, independently of the direction in which his avatar was moving (Rollings & Adams, 2003, p. 293).

In both Gauntlet and Robotron, later updates based on the originals were released. However, if in the case of Gauntlet the gameplay remained generally intact due to its already rich design, Robotron's move to a 3D environment caused a negative impact on the game's playability. While in the original game all the game activity was visible onscreen, the recent 3D version introduced off-screen gameplay. This resulted in the player being killed by enemies that appeared suddenly from the non visible area of the game (Rollings & Adams, 2003, p. 293).

Another game mentioned by the authors is Centipede; a game many consider incorporating *near-perfect* gameplay due to the placement of the game's various elements. However, the 3D update for Centipede did not have the expected result. Centipede was originally successful because players weren't required to *think* to play. The player's actions we're done on a subconscious level. However, the introduction of textures and a 3D environment made it more difficult to play (Rollings & Adams, 2003, p. 294).

The evolution of 2D shooters resulted in the 3D first-person shooter. The mentioned authors present the idea that 3D shooter games are restrained by their hardware limitations. However, these days, those limitations are diminishing with the advance of technology in terms of graphic processing.

These technological advancements have helped the growth of the video game market, including the sales of games of the first-person shooter genre. According to a Video Game Journal publication, the first-person shooter genre is one of the most appealing to create games for, defining it as "a growing and highly attractive genre." Furthermore, the same report indicated that the first-person shooter offers "instant gratification" and that "just a few minutes of play can quickly satisfy the gaming urge" (Cifaldi, 2006).

This idea alone helps to understand not only the value of the first-person shooter genre but of the video game industry as well. It is therefore necessary to continue developing quality video games. However, this is only possible when video game developers have complete knowledge of what occurs in video games which in turn can be accomplished through video game evaluation, an area which will be explored in the following section.

6. Video Game Evaluation

We've seen earlier that the video game industry is one that generates billions of dollars in sales. We've also seen that the industry is in constant growth and expanding. The need to deliver more enjoyable games has already been studied by various people. The problem of "how" to do so has also been studied by many. In the present section, some of the work previously done in this area and how they came up with solutions to improve video games and the overall game experience will be looked at.

Furthermore, in the present section some of the existing research and projects done in the area of video game development that did not use the eye tracking technology as well as a few that adopted the technology will be explored.

6.1. Without Eye Tracking

6.1.1. Melissa Federoff's Heuristics Study

Melissa Federoff's study, *Heuristics and Usability Guidelines for the Creation and Evaluation of Fun in Video Games* (Federoff, 2002), proposes a list of heuristics and suggestions that could be used by game developers to better develop and design video games. To do so, *she examined implicit and explicit heuristics and usability evaluation processes utilized by a leading game developer* (Federoff, 2002). Also, Federoff spent a week observing and later interviewing five people from a game developing company, each with an important role and contribution to the game development process.

Federoff's study begins with a thorough analysis, based on a literature review, of some important questions to her study. Federoff looks into the concept of Usability, defined by the ISO standard 9241, as presented in the *Usability* section; defines the notion of *fun* crossing opinions of authors such as Chris Crawford (Crawford, 1982), David Myers (Myers, 1990), Thomas Malone (Malone, 1982), among others. Later, she defines what aspects of a game can be evaluated taking into consideration Chuck Clanton's (Clanton, 1998) proposal of dividing game usability issues into the areas of game interface, game mechanics and game play. Using this, she continues on to identify several game design issues and associates each one of them to the areas Clanton mentioned earlier. Finally, she questions the need for the use of heuristics identifying, further on, in what way Nielsen's "Ten Usability Heuristics" (Nielsen, 2005), as seen in the *Evaluating Usability* section, can be applied and used in evaluating game usability.

In regards to the method that she applied, as mentioned above, she spent one week at a leading game development company in the San Francisco Bay area of California, U.S.A. Every day, during those 5 days, Federoff observed a different person of that team including the Director, the Art Lead, the Lead Level Designer, the Lead Programmer as well as the Producer. Federoff presented, as well, three questions to which she tried to find answers through her study: *what are the implicit heuristics being applied within a game development company?*; *what are the explicit heuristics being applied within a game development company?*; *what usability evaluation measures are being used within a game development company?*

Federoff's study at the game development company took place while the group was in the process of developing a game on a two year plan, in which five of those months were reserved for prototyping. Federoff's work took place during the prototyping phase, specifically during the end of the first month of that phase.

The methodology Federoff used consisted in two techniques: participant observation while collecting notes; and inquiry, through the use of a semi-structured interview. (1) The observation period Federoff planned with each participant lasted for 7 of the 8 hours of the work day. The last hour was reserved for an interview between Federoff and the team element she had spent the day with. She instructed each of the participants to act in a natural way but each one rearranged their working behaviour to better accommodate Federoff's study needs: two participants tried to make Federoff's experience a more informative one; two others, while working, made sure they processed some of their thoughts aloud so that Federoff could better understand what they were doing; finally, one of the participants allowed Federoff to attend some of the meetings he was involved in. Apart from the observation process, Federoff was allowed to attend team meeting as well as consult some of the game documentation: game production plan, design document, prototype description and prototype plan. (2) The interview with each of the game team members was conducted during the last hour of the work day. Federoff asked a variety of questions she grouped into the following: questions specific to the individual's philosophy; questions specific to the company; questions specific to the job role.

Prior to the study, Federoff was able to pilot test the interview part of the study although she was not able to test the entire study before she conducted it. Her test subject, also involved in the game design industry, found that she had difficulty understanding some of the vocabulary Federoff used in her questions. However, even though she expected that those problems could arise, she decided to go forth with the questions to understand the case study participant's views on usability in game design.

With the data Federoff received from here participants, she was able to identify some heuristics and as each one was identified, she coded them for one of the specific game usability areas (interface, mechanics or gameplay). After coding and counting the number of times each heuristic was mentioned, she compared the list with the heuristics she had identified during the literature review.

Melissa Federoff's study presented various results. First, and as Federoff states she anticipated, her participants felt some difficulty in analysing the idea of usability in video games. From 4 of the 5 participants she received 3 distinct ideas of what the usability of a game could be. Only one of the participants appeared to have an understanding of the concept, explaining that it made him think of a tool which is in some ways problematic due to the fact that games are intended to have a ludic nature. Although the term usability did cause some discomfort to the majority of the participants, when asked what they considered to make a game fun as well as what aspects of a game should be evaluated, the discussions between Federoff and the participants began to flow with much more ease resulting in the identification of issues related to gameplay, interface and mechanics.

Some of the heuristics identified by her literature review were not identified by the study participants. On the other hand, some of the ideas her research turned up we're not shared by the participants in her study. Finally, there were 4 heuristics that were mentioned by the case study participants as well as found in the literature review which indicates their importance in the video game design industry.

Finally, Federoff's study presents a list of four suggestions for implementing a more formal usability procedure that are related to prototyping, testing, a post-mortem phase and a usability evaluator. (1) Federoff suggests that prototyping should be a part of every game. Implementing a prototyping phase could prevent financial failures or at the minimum, allow a company to understand if a game will or will not work before full production is undergone and major investments are made. Besides this, prototyping also allows for problems to be identified earlier on in the development process. (2) A second suggestion is related to testing. Although it's only possible to fully test with a finished product, a prototype allows testing on a slimmed down version of the video game. (3) The third suggestion is related to the *post-mortem* phase, a phase that one of the participants of the study mentioned he thought wasn't occurring enough. The possibility of discussing what went wrong or what went well during the game development process after the game is finished could help prevent errors from being repeated. During this phase, and taking into account that the game is already on the market, allowing external subjects to play the game and evaluate it as well as their satisfaction, could provide important feedback. If usability testing isn't possible, exploring expert usability evaluation methods could be useful to determine problems with a game. Finally, (4) a fourth suggestion from Federoff is that a usability evaluator with knowledge in gaming should be part of a game company staff. Even if only one person, they can help in the development and evaluation of prototypes as well as assist with tests and usability evaluations.

6.1.2. Desurvire, Caplan & Toth's Heuristics Study

Desurvire, Caplan and Toth's study, *Using Heuristics to Evaluate the Playability of Games* (Desurvire, Caplan, & Toth, 2004), focuses, much like Melissa Federoff's study, on the use of heuristics to evaluate video, computer and board games. They present the Heuristic Evaluation for Playability (HEP), a set of heuristics used to evaluate video, computer and board games and tested them to understand their validity and real effectiveness compared to standard user testing methodologies.

Their study commenced with an analysis of the history in software and game heuristics development. They concluded that Nielsen's (Nielsen, 2005) list of heuristics, as seen previously in the *Evaluating Usability* section, were useful when combined with user studies. However, they also refer that for game development, a similar list of heuristics is necessary. They define four categories of game heuristics: (1) game story which is related to the plot and character development; (2) game play refers to the problems and challenges that a player goes through to win a game; (3) game mechanics that focuses on the programming that provides the structure by which units interact with the environment and finally, (4) game usability involves the game interface as well as the elements the players use to interact with the game, that is, the mouse, the keyboard and the controller, for example. Federoff's (Federoff, 2002) work, as mentioned above, as well as Falstein and Barwood's (Falstein & Barwood, 2006) studies are two examples mentioned by the authors to confirm the ongoing work in game heuristics development.

The authors proposed their own list of heuristics, the Heuristic Evaluation for Playability (HEP), which was written up considering the literature review they had done. The HEP heuristics were also examined by various experts in the area of playability and game design. Their list was put to the test using a game that was being developed. They used a prototype developed using Macromedia Flash.

While performing the HEP, the evaluator was asked to focus on how the heuristic was or not supported as well as identifying the playability issue in cause.

After this evaluation, the authors had users play the prototype during a period of two hours. Each of these sessions, performed individually, took place in a similar environment to the one they would actually play in when the game was completed. The participants in the study were asked to think aloud (a process previously described in the *Evaluating Usability* section) and during that time were also subject to some questions. After the two hour period, the player was then debriefed and asked to fill out a questionnaire of satisfaction. Throughout the playing session an evaluator recorded a log of all of the player's actions, comments, failures and missteps and later coded them as a positive or negative response to the game experience. They distinguished positive from negative experiences considering positive experiences as anything that increased the player's pleasure, immersion and challenge of the game and negative experiences as situations in which the player was bored, frustrated or simply wanted to quit the game. After all the sessions had been completed, problems related to playability were identified and solutions for these problems were thought up. Finally, each issue found was attributed a severity level based on its consequence and the user's ability to continue with game play.

The authors' study proved to be effective at revealing certain playability issues, especially in two of the four categories: game story and game usability. In the game story category, 6 out of the 8 heuristics proved to be useful in uncovering playability issues. In the game usability category it was 11 out of the 12 heuristics. For the remaining two categories, game play and game mechanics, only 7 out of 16 and 4 out of 7 heuristics were identified, respectively. This is due, according to the authors, to the fact that the game was at an initial stage, a moment when game play and game mechanics aren't fully implemented.

In conclusion, the authors believe that user testing is an essential part of any playability evaluation mostly because a game designer can never truly predict a game user's behaviour. They also admit that the Heuristic Evaluation for Playability (HEP) is very useful for earlier stages of game development, prior to the development of possibly expensive prototypes. On a final note, in terms of future research, the authors believe that understanding how HEP could be used in the later stages of game design would be a positive approach as well as understanding the differences of HEP results when performed by designers and playability experts.

6.1.3. Tracking Real-Time User Experience

Tracking Real-Time User Experience (TRUE): a comprehensive instrumentation solution for complex systems (Kim, Gunn, Schuh, Phillips, Pagulayan, & Wixon, 2008) takes video game analysis to a new level. Their study as well as their system, TRUE, is a result of an analysis of behavioural instrumentation with other HCI[10] methods.

The study begins with a first analysis of the concept User Initiated Events (UIEs), events that are a result of a user's direct interaction with a system. The potentialities of logging UIEs such as number of errors or time to complete a task so that certain user behaviours are more accurately calculated are also discussed. As

[10] Human Computer Interaction

they suggest, although the system design itself might seem simple, the actual process of recording UIEs is not. However, despite these difficulties, solutions have been developed on various levels to solve these issues.

UIEs are not, however, a concern of the present or recent past. In the field of psychology, behaviourist B.F. Skinner constructed the Skinner Box, a device capable of logging an animal's UIE. This device proved to be important for the field in the sense that it presented significant differences from other devices and methods used to record animal behaviour at the time. The Skinner Box alone was able to log the animal's behaviour and did not need the researcher to be present to record information (Skinner, 1932, 1938 apud Kim et al., 2008).

The authors describe the TRUE system as being one similar to other techniques related to instrumentation and log file analysis. However, one of the differences between TRUE and other techniques is that TRUE allows its analysts to look at streams of data rather than just aggregated frequency counts. Equally, while actions are performed, TRUE systems log various sequences of events as well as insert a time stamp for each of those events. This is important as well as necessary to understand a certain sequence of events and to be able to produce correct recommendations for a certain product. Another difference the authors point out relates to the information that the TRUE system collects. Rather than just collecting low level system events such as mouse coordinates, the TRUE system can collect a set of events that not only contain the event system of interest as well as the contextual information relative to that event. As they exemplify, in a racing game, not only is it important to record the crash but also contextual information related to the crash: the track that was being raced on, the weather conditions at the time, the car that was being used and so on. All these instances of information are necessary for an accurate understanding of what caused the accident.

Besides the aspects mentioned above, the TRUE system also incorporates an additional data source: attitudinal data; an approach that allows the analysts to gather user information that traditional UIE systems miss. Considering the racing game previously mentioned, when using TRUE to test the game, at the end of the race, a survey would appear questioning the player about how fun the game was as well as the difficulty he or she might have experienced. These inquiries are important due to the fact that had they not been done, wrong assumptions might have been made regarding how easy a game was or whether or not the game had a problem to be fixed. The combination of the acquired behavioural data as well as attitudinal data is important for a better understanding of how users experience products.

One of the big advantages of the TRUE system is its use of powerful ways of visualizing and manipulating data which facilitates the course of finding problems and the core issues that cause it. Even though the way TRUE is used to present data varies from question to question, the approach used for viewing and interacting with the data is identical. As the authors indicate, video is one of the most powerful forms of data visualization and one they use with the TRUE system. For a better data analysis, they capture video with users interacting with the system and later associate it to the time stamp of the complementary event. This creates an indexed video and allows the analysts to jump to any part of the video they need. This process allows for a better understanding of the context in which problems occur, an idea discussed before. Overlying video data with attitudinal data has proven to be an effective approach to understand how users interact with systems. The system allows that the analyst to comprehend, with just a few clicks, how the user is interacting with a product to an understanding of what problems the user is encountering while interacting.

The authors' work is broken down into two main case studies that illustrate how they applied the TRUE system. The first study, as they define it, takes full advantage of the rich contextual information, drill down reports, attitudinal data, and video to identify problems and verify fixes (Kim et al., 2008). The second case illustrates how the TRUE system was deployed in a BETA context, enabling the authors to observe naturalistic behaviours of thousands of users over extended periods, using it to identify issues that emerged over time (Kim et al., 2008). For the present study, the first example will be thoroughly looked at.

The first study involved playing Halo 2, a first-person shooter (FPS) game released in 2005. Their procedure consisted in asking 44 participants, all with prior experience in FPS video games, to play the Halo 2 single-player campaign. The 44 participants were divided into two groups (session 1 and session 2) and were asked to play the campaign as if they were at home and without changing the difficulty setting.

Data related to player deaths, the time of the death, who (i.e. what enemy) killed the player and other information helped the authors understand the UIEs they studied. In addition to this, they also collected attitudinal data during the game. Every three minutes the game would be paused and the players would be prompted with a question related to the game. For example, while playing a certain section of the game, the player would be prompted with a question related to the difficulty of the game at that moment.

With the TRUE system, the authors were able to understand the players' game performance throughout the various levels. In the example they report, they analysed player deaths. Their analysis showed that player deaths were more frequent and in greater number than they expected, especially during Mission 10. However, to fully understand the reasons for this occurrence, it was necessary to dig deeper. The TRUE system allowed them to analyse specific UIEs registered in that level. With that, they were able to understand that there might have been a problem related to the third encounter of that mission. Despite knowing where the problem was occurring, the authors still did not fully understand what was behind the player's difficulty during that specific moment. The facilities of TRUE allowed them to *drill down*, as they call it, deeper into the problem and understand the specific reasons of the deaths. With this, they were able to detect that 85% of the registered deaths were caused by one of the enemies (*the Brutes*) the players encountered during the mission. A further *drill down* allowed them to understand that the players were dying primarily through three ways. This was important because it allowed them to quickly understand the causes of the players' deaths. Despite the information gathered up to that moment, the cause of the participant's deaths wasn't fully understood. Nevertheless, TRUE allowed them to visualize videos of exactly what was happening during the game. With the game designers at their side, they were able to conclude that the players' deaths were mostly caused by hits from a plasma grenade. While watching the videos, the game designers perceived a problem in the game, a problem only they could understand: the Brutes in that specific section of the game were throwing grenades faster and with less of an arc than in other sections, reducing the players' reaction time.

Having found the problem, the designers were able to make changes related to the difficulty of that section as well as the enemy behaviour.

Running a second session of the game with distinct participants, they confirmed that the number of deaths in that specific mission decreased significantly from 311 in the first session to 34 in the second, after the game had been corrected. Fearing that the changes made might have turned the game to easy to play, their analysis on the attitudinal data revealed that ¾ of the players selected the option "about right, I'm making good progress" when they were prompted to evaluate the game difficulty at that moment. Only 9% of the players felt the game was too hard and 4% thought it was too easy to play. In the first session, 43% indicated the game too hard to play and 43% about right.

Both of the studies the authors completed prove that the TRUE system is in fact a valid and useful technology. As the authors explain, they needed a method that would allow them to complete 4 actions:

detect issues and understand root causes in the same way usability testing does; support design iteration to the extent that RITE[11] testing affords; incorporate attitudinal behaviour in the manner of surveys and understand the naturalistic use of our products as is found with ethnographic methods (Kim et al., 2008). This is necessary *in the context of the videogame industry, where development budgets are big, business risk is high, schedules are tight, and demonstrating value in a timely way is a necessity (*Kim et al., 2008). Those 4 elements resulted in the development of the TRUE system:

> *(…) we developed TRUE, an instrumentation system that combines the strengths of all of these HCI methods. By recording streams of data and pertinent contextual information in event sets, we retain the ability to detect issues and determine their underlying cause (…). By using powerful visualizations, hierarchically organized reports that afford user researchers to drill down to specific details, and linking directly to game play video, we are able to locate quickly the problem spots, understand the issues in context, make fixes, and test again to verify fixes, much like RITE. By including attitudinal data, we tap into the power of surveys in helping understand how people emotionally experience our products.*
>
> *(Kim et al., 2008)*

In fact, the TRUE system has been a valuable asset to the video game industry. In the past 5 years, the technology has helped improve more than 20 games of various game genres and game platforms.

6.2. With Eye Tracking

6.2.1. El-Nasr and Magy Seif

Magy Seif El-Nasr and Su Yan's study, *Visual Attention in 3D Video Games* (El-Nasr & Yan, 2006), defends the current need to understand visual attention patterns within an interactive 3D game environment as it is an important area of research to better improve video games (El-Nasr & Yan, 2006). Furthermore, understanding player's visual attention patterns can help game designers enhance games in terms of level designs, textures, colours and objects.

As they point out, visual attention can help improve video games and their design by increasing game player engagement and decreasing their frustration during the game. *Many non gamers get lost in 3D game environments, or they don't pick up an important item because they don't notice it* (El-Nasr & Yan, 2006). If game designers knew how players visualize a game, it would be easier for them to understand where to put items in a level or even how to mix colours to draw player attention, eliminating therefore, the problems mentioned above.

El-Nasr and Yan's study also aims to understand, as they point out, whether visual attention within a 3D game follows the bottom-up or top-down visual theories. Additionally, their study addresses the questions mentioned above as well as presents information related to player's visual attention patterns in two different game genres: action adventure and first person shooter. They hypothesize that these two genres would stimulate specific visual attention patterns related to the activities the player is involved in during the game (El-Nasr & Yan, 2006).

[11] RITE – Rapid Iterative Testing & Evaluation: a usability testing method that shares similarities with the Iterative User-Centred Design Principles (Norman, 1998).

The possibility of studying these questions, although not impossible, has its complications. While 2D interfaces are easier to study, a 3D environment presents new challenges. The authors present therefore, a new method using eye tracking to analyse data within 3D environments.

The design of their experiment was based on three hypotheses: (1) *Bottom-up visual features affect players' perception of a 3D video game environment. We specifically focus on colour and motion, and study their effectiveness in grabbing players' attention in a 3D environment*; (2) *Since video games are highly goal oriented, we hypothesize that top-down visual features are more effective in attracting players' attention than bottom-up visual features*; (3) *Eye movement patterns may differ among different game genres. We believe that eye movement patterns reveal the way that game players visually perceive the 3D environment. Since the pace and visual composition of game levels are different in different genres, we hypothesize that eye movement patterns among different game genres are also different* (El-Nasr & Yan, 2006).

The authors' study involved six participants that attended the University of Pennsylvania State. As they mention, they were aware of the limitations of such a small participation group, defending themselves however with their time limitations and explanation that this experimentation is just a preliminary study in a new area of research. The six participants filled out a survey prior to the experiment to evaluate their gaming experiences. They were later divided into three groups: novice gamers, casual gamers and core gamers. Their inquiry resulted in the division of 2 participants per group, 2 of which were women. To carry out the procedure they used the ISCANERTL-500 head-mounted eye tracker to collect the required data.

Before the participants began the final study, they were asked to get familiar and comfortable with the eye tracker equipment. Therefore, they played a fighting game, different from the game used in the final procedure. After all participants felt comfortable with the equipment, they proceeded with the calibration of the eye tracking system. Finally, for the study, they were asked to play two games during 10 minutes: Legacy of Kain Blood Omen II, an action-adventure game and Halo II, a first person shooter game. Their game play was also recorded to video for further analysis.

Having analysed the data obtained, the authors' found that bottom-up visual features, including colour contrast and movement, subconsciously triggered the visual attention process, thus verifying the bottom-up visual attention theory (El-Nasr & Yan, 2006) just as they hypothesized. To illustrate their conclusions, they exemplify with actions occurred while participants played Legacy of Kain Blood Omen II.

> *In one video segment, the player wanders around in a big castle trying to find an exit. (…) There is a tiny object that changes colour to red and becomes brighter, and thus becomes more salient according to the bottom-up visual attention theory. (…) This object however was not on the right path to an exit, and thus would distract participants from the exit route. (…) We found that only two out of the six subjects followed the path of the object. When the object appeared on the screen with the same colour as the background, none of the two participants noticed it. They went straight to the door at the end of the path and did not pay attention to the object. But as the object began to change its colour to bright red, both participants paid attention to it. This confirms the theory of saliency described by the bottom-up visual attention theory.*
>
> *(El-Nasr & Yan, 2006).*

Part of their analysis also allowed the authors to conclude that since action-adventure games are mainly goal orientated, top-down visual features control players' attention more than bottom-up visual features (El-Nasr & Yan, 2006). According to their data and this idea, if game designers intend for objects to be more noticeable when playing, they should be positioned such that the position matches a player's goal orientated visual search pattern. To exemplify, if the goal of a player is to find an exit, then doors, windows or stairs should be considered as places to set objects as they will be easily noticed and have a similarity to the player's goal.

The authors' study also focused on the first person shooter game Halo II. Their study results showed that in this game, the participants focused mainly on the centre of the screen where the cross indicator is located. This tendency is contrary to what was found for the action adventure game where there is more time to visualize the game since it is played at a slower pace.

To sum up the authors' study, they conclude that they have presented evidence, as reported, that in 3D video games, there is both bottom-up and top-down visual patterns and that eye tracking can provide information regarding how this is verified. However, limitations related to the number of participants and the number of games used to run the study should be considered for future research.

6.2.2. Can eye tracking boost usability evaluation of computer games

Sune Alstrup Johansen, Mie Norgaard and Janus Rau's study, *Can Eye Tracking boost usability evaluation of computer games* (2008), explores how eye tracking can address three core challenges faced by computer game producer IO Interactive (IOI) from Denmark in their on-going work to ensure that games are fun, usable and challenging. These challenges are: persuading game designers about the relevance of usability results; Involving game designers in usability work; identifying methods that provide new data about user behaviour and experience (Johansen, Nørgaard, & Rau, 2008).

They present a similar concern that has been discussed by other researchers: the use of usability evaluation methods [(Federoff, 2002); (Kim et al., 2008); (Nacke & Lindley, 2008) & (Pinelle, Wong, & Stach, 2008)]. However, as seen before, since a video game's specific goals are different from regular systems, traditional usability evaluation methods often fail when they are used to evaluate games. The idea of using the think aloud protocol (Dix et al., 1998) while a player is playing a game is, as the authors suggest, practically impossible. For that reason, the authors discuss the use of eye tracking as a tool to assess some of the usability related problems that the company in cause (IOI) face. The authors affirm, however, that they do not intend to prove that all usability related problems can be fixed by means of eye tracking data. What they do expect is that the eye tracking results may provide some information about the importance of usability results.

First and foremost, they present the IOI game development company, a group recognized for developing rich games in terms of gameplay but simultaneously difficult for novice players. For that reason, IOI increased their attention in usability evaluation.

In what concerns the first challenge mentioned earlier, the authors hypothesize that the use of quantitative results (through the use of statistics, maps and graphs) migh persuade game designers to approach usability not only in terms of qualitative data but also quantitative. As for the second challenge, the authors hypothesize that allowing designers to participate with ideas and feedback in the usability evaluation process will make it easier for them to accept the results the evaluations produce. Finally, as mentioned, the use of traditional usability evaluation methods is not always a reliable option in game evaluation. Furthermore, even the combiantion of various methods as used by IOI may not cover all aspects crucial to video game evaluation.

The authors present the idea that the use of the retrospective think-aloud process is one of having received valuable attention. This technique allows the player to interact with the game without him or her being disturbed as well as providing a more accurate and valid test. Furthermore, the authors describe the process as one that increases the player's attention towards the task and therefore isn't distracted by other cognitive loads he or she might experience through the parallel use of the think-aloud protocol and the game playing task (Johansen, Nørgaard, & Rau, 2008).

Finally, the authors believe that the use of eye tracking could provide interesting information about user behaviour that could be used with other usbaility evaluation methods.

In the work the authors present, there is the case of the IOI team developing a new game in which players had dificulties in resolving a problem related to snipers in a scenario. The questions that surfaced dealt with the snipers' appearance in the game. Their eye tracking data provided them with information that indicated that increasing the light in the problematic scenario would help resolve the problem of player's not being able to see one of the snipers that appeared in that one particular scene. As seen before, eye tracking technology allows researchers to collect quantitative data such as fixation durations – indication of a difficulty in extracting information or interest in a particular object – that allows researchers or designers to understand how the game interface is performing in terms of usability (Johansen, Nørgaard, & Rau, 2008).

Therefore, to conclude their work, the authors believe that eye tracking can be useful in game evaluation especially when player focus is imperative for the gameplay as well as player distractions being devastating for a player's survival in the game. Furthermore, the uniqueness of eye tracking data is an incentive for game designers to participate in the usability evaluation of a game.

part two
the empirical study

7. Empirical research context: case study

7.1. Characterization of the target group

The number of individuals that volunteered to participate in the case study was 41. The participants' ages were between 18 and 45 and both male and female individuals were selected. To participate in the study, participants were required to have some technological literacy with computers (the platform running the video game) and a minimum interest in video games.

For study purposes, the participants were divided into three categories: inexperienced players, casual players and hardcore players. This categorization was established according to the following criteria: volunteers with less than 5 hours of gaming experience per week would be considered inexperienced; those who played video games from 5 to 10 hours per week would be considered casual players; finally, those who dedicated more than 10 hours a week to playing video games would be considered hardcore gamers. Furthermore, this categorization did not only take into consideration gaming experience in general but also experience with First-person shooter video games, the video game genre chosen for the game used in the empirical study. The presented criteria were chosen taking into account the lack of consensus in what concerns a hardcore or an inexperienced player. Nonetheless, the chosen criteria was somewhat based on the ideas of one author that specifies the division of hardcore and casual gamers based on the amount of time played and the attitude towards games in general (Barreiro Jr., 2008).

Due to the interest demonstrated by the academic community, the final number of participants surpassed the original planned number. The benefits and risks of altering the original number of participants were, however, taken into consideration. Nevertheless, it was believed that the study would only benefit from the great interest expressed by the community and for that reason; the total number of participants that contributed to the study was 41.

Upon volunteering, each participant was asked their *gaming experience* according to the criteria mentioned above. Having registered all of the participant's experience, these were divided as follows: 12 inexperienced gamers; 16 casual gamers and 13 hardcore gamers.

7.2. Characterization of the study object

Call of Duty 4: Modern Warfare is a First-person shooter (FPS) video game. It is the fourth game of the Call of Duty series and the first to take place in a modern setting and outside of World War II (in 2011). It was announced in April of 2007 and released in November of the same year (Call of Duty 4: Modern Warfare Wiki).

7.2.1. Gameplay

In single-player mode (or Campaign Mode), Call of Duty 4: Modern Warfare (CoD4) presents a film-like plot that differs from the previous Call of Duty video games. Previous games in the series were based on a three country-specific campaign style whereas in Call of Duty 4, the game is developed similarly to a film through the view of Sergeant Paul Jackson (USMC 1st Force Recon) and Sergeant "Soap" MacTavish (British 22nd SAS Regiment). CoD4 also integrates a series of cameo-style missions where the player controls other game characters. Furthermore, CoD4's move to modern warfare has introduced a series of new weapons and technologies to the series.

Figure 8 - Call of Duty 4: Modern Warfare game cover [retrieved from: http://www.gamespot.com/pc/action/callofduty4modernwarfare/index.html]

In multiplayer mode, Call of Duty features team-based and individual multiplayer modes[12] that can be played on various maps[13]. Each of the modes has an objective that requires strategic actions to complete. Game players can use UAV (unmanned aerial vehicle) reconnaissance scans, air strikes and helicopters to aid in their game strategy when completing three; five and seven-enemy kill streaks, respectively. A

[12] For complete list of Call of Duty 4: Modern Warfare game modes consult Table 5 [Appendix].

[13] For complete list of Call of Duty 4: Modern Warfare game maps consult Table 6 [Appendix].

multiplayer game ends when either a team reaches a chosen number of points or the previously selected game time expires. However, in the case of a tie, Sudden Death mode is activated where the last man standing or the first team to complete the objective wins.

7.2.2. Game Plot

The game orbits around a Russian ultranationalist, Imran Zakhaev, determined to return to his homeland. Aware that the United States will not allow this, he finances a rebellion in the Middle East led by his ally Khaled Al-Asad to draw attention away from Russia. The prologue of the game begins with the player taking the role of Sgt. “Soap” MacTavish in his first adventure as part of the SAS. Here, the player will meet other members of the SAS team as well as go through a basic game tutorial. From here on out, the player participates in the first mission of the game which is to intercept a cargo ship in the Bering Strait along with Captain Price and Gaz. The game is composed of three acts[14], each having a series of missions to be completed. The story leads up to the death of Zakhaev after being shot by MacTavish in the final scene (Call of Duty 4: Modern Warfare).

7.2.3. Game Selection

Of the various existing video game genres available on the market, the final selection was reduced to either the First-person shooter or the Role-playing game genres. After considering the potentials associated to both genres, the choice fell upon a FPS and furthermore, the Call of Duty 4: Modern Warfare video game for various reasons.

The main reason that supported this choice was the possibility of controlling the game environment the participants would encounter. Bearing in mind the project’s objectives, it was essential to create a similar environment for all participants so that no participant was favoured in comparison to another. As will be seen further on, this was possible through the use of a patch applied over the game. This patch inserted *bots* with artificial intelligence that could serve as enemies or as team-mates according to the game mode selected. The patch also enabled the participants to play alone, avoiding therefore, a multiplayer environment. Therefore, the participants were able to play the same game mode repeatedly and with guarantees that the game settings and environment was similar to all other participants. Another reason that favoured the choice of CoD4 was the large amount of modes and maps available. A greater offering of maps and modes allowed a more precise selection of a game environment that best suited the needs of each of the study objectives. Another important factor that weighed in on the selection of Call of Duty was some of the existing game reviews by various acclaimed reviewers such as GameSpot (video gaming website), Game Informer (video game magazine), IGN – Imagine Games Network (multimedia website) and the Academy of Interactive Arts & Sciences – AIAS (organization that promotes computer and video games). GameSpot[15] gave CoD4 a 9 out of 10 score; Game Informer credited CoD4 with a 10 out of 10 rating; IGN[16,17] gave the game a 9.4 out of 10 score as well as claimed it the “the best shooter of 2007”; finally,

[14] For complete list of Call of Duty 4: Modern Warfare acts consult Table 7 - List of Call of Duty 4 Acts, Missions and corresponding used character [Appendix 2].

[15] Website: http://www.gamespot.com/pc/action/callofduty4modernwarfare/review.html [Consulted: May 20, 2009]

[16] Website: http://pc.ign.com/objects/902/902593.html [Consulted: May 20, 2009]

[17] Website: http://goty.gamespy.com/2007/overall/13.html [Consulted: May 20, 2009]

AIAS[18] prized CoD4 with various awards including "Action Game of the Year", "Console Game of the Year" and "Overall Game of the Year".

Finally, of the existing research available related to video game evaluation, many of these used first-person shooter video games in their own case studies suggesting, therefore, that the FPS genre is one that has potential when studying video games is at stake.

7.2.4. System Requirements

Due to its recent release and the advancements in computer graphics development, Call of Duty 4: Modern Warfare presents a list of system requirements that exceed the capacity of older systems.

In terms of the minimum system requirements necessary to run CoD4, a Pentium IV 2.4 GHz processor or faster (or equivalent); 512 MB of RAM, 8 GB of Hard Drive space and a GeForce 6600 / ATI Radeon 9800 Pro graphics card or better graphics is required.

However, the recommended system requirements are slightly more demanding: a 2.4 GHz Duo Core processer or faster (or equivalent); 1024 MB of RAM, 8 GB of Hard Drive space and a GeForce 7800 / ATI Radeon X1800 graphics card or better is required.

7.3. Characterization of study protocol and presential context setup

The empirical study consisted in participants playing the First-Person shooter video game Call of Duty 4: Modern Warfare. The study was divided into two 5 minute tasks. The possibility of combining various maps with various modes allowed a more meticulous selection of what maps and modes to be used for the two tasks. The idea was to find two large and content-rich maps where two distinct modes could be played. The choices fell upon the *District* and *Strike* maps, as seen in Figure 9.

Figure 9 - Call of Duty 4: Modern Warfare game maps (left - District; right – Strike) [retrieved from: http://battletracker.com/index.php?page=CoDGameInfo&action=maps]

[18] Website: http://www.interactive.org/awards/annual_awards.asp?idAward=2008 [Consulted: May 20, 2009]

The chosen maps, *District* for the *Free-for-All* mode and *Strike* for *Domination* mode, were considered adequate for the objectives at hand: they both offered diversity in scenery and various places to explore including a variety of vehicles and barrels ready to blow up in the *District* map and various buildings to explore in the *Strike* map.

The first task consisted in the participants playing the multiplayer game mode *Free-for-All* whereas the second consisted in playing a different multiplayer game mode, *Domination*. *Free-for-All* consists in every player playing for him/herself. *Domination*, on the other hand, consists in flags being placed in certain parts of the map. These flags all start neutral and it is the player's objective to fight and hold the most flags; if the flags are in the players' team's possession, they should be held and protected whereas if they are held by their enemies, they should be conquered. These two game modes were specifically chosen due to the primary objectives they hold. In the *Free-for-All* mode, the participant is able to wander and explore the map freely while in the *Domination* mode, the placement of flags on the map and the objective to secure and conquer them as a team implies that rational decisions be made in terms of how to reach the specified places the flags are placed.

Despite both game modes being traditionally multiplayer, for the empirical study procedure, they were played as single player; that is, participants played on their own. As mentioned earlier, to create the original multiplayer scenario, a patch was applied over the game that inserted bots with artificial intelligence into the modes the participant would play. Hence, in the game mode *Free-for-All*, the bots acted as the participant's enemies whereas in the *Domination* mode, the bots were distributed as the participant's team-mates and enemies.

Each session with a participant had a duration of approximately 20 minutes. Upon entering the usability laboratory set up for the study, each participant was asked to sit in front of the eye tracker as can be seen in Figure 10. From here, each participant was briefed on the objective of the study including the two tasks they were about to complete. The essential and default game controls were then explained: *W, A, S, D* (front, left, back, right) for movement; *R* for reloading; *C* for crouching; *G* for throwing grenades; *1* and *2* to switch between guns; left button for firing/shooting and right button to use the gun scope. However, more experienced participants were allowed to configure the controls according to their needs. Furthermore, and due to the technological implications associated to the external video option, participants were informed of the existence of a minor lag between their mouse movement and the actual result of the mouse movement in the game. The first task (*Free-for-*All) was also chosen taking into account this issue. The fact that there is no specific objective in *Free-for-All* except to combat, allowed the participant to adapt to the lag so that in the second and more objective task, their participation was less influenced by the technological limitation at hand.

Figure 10 - Participant in front of the Tobii Eye Tracker preparing for study

Before beginning the tasks, the participants' experience was once again verified and confirmed for a second time and then inserted as a variable along with their genre in the Tobii software. Each participant was given a specific ID according to their order of participation. Therefore, the first participant was given the ID J1 (*j* for *jogos* – games in Portuguese), the second J2, and so forth. The next step consisted in asking each participant to place themselves in "gaming" position, a position they felt comfortable playing in so that they would not constantly move in their chair. After doing so, their eye position was centered on the eye tracker and the calibration process was explained. After each participant's eyes were successfully calibrated, a second ID that distinguished the task they were about to carry out was inserted. As a result, the first task was identified as J*n*_t1 and the second task as J*n*_t2. While the participants calibrated their eyes, the game was setup (on the stimulus computer) in terms of task duration, map and game mode. After completing these tasks, the external video recording was initiated and launched. Participants were then informed to choose one of the two available teams as well as a class of guns. From here, players were left to complete the first task of the procedure. Once completed, the participants were then informed of the nature of the second task and therefore, explained that the mode consisted in the participants playing as a team with other bots to try and conquer enemy flags and defend previously captured flags. They were informed that all flags began neutral and were represented as a white triangular symbol on the in-game map and semi-transparent symbols on the screen. If the flags had been conquered and were in the possession of the participant's team, they were represented as green triangles whereas if they were in enemy possession, they would be represented with a red colour. Before beginning the second task, the task ID was associated to the participant ID as mentioned above. From here, the game was launched and the external video recording was initiated a second time.

After completing the second task, participants left the eye tracking station (Figure 11) and were asked to take a seat and handed a questionnaire that they were required to fill out while discussing various core questions related to the experiences they just had, as well as key aspects of the game they had just played.

Figure 11 - Tobii Eye Tracker workstation

In terms of the laboratory and presential context that was set up, the setup of the room used to execute the empirical study resembled what can be seen in Figure 12.

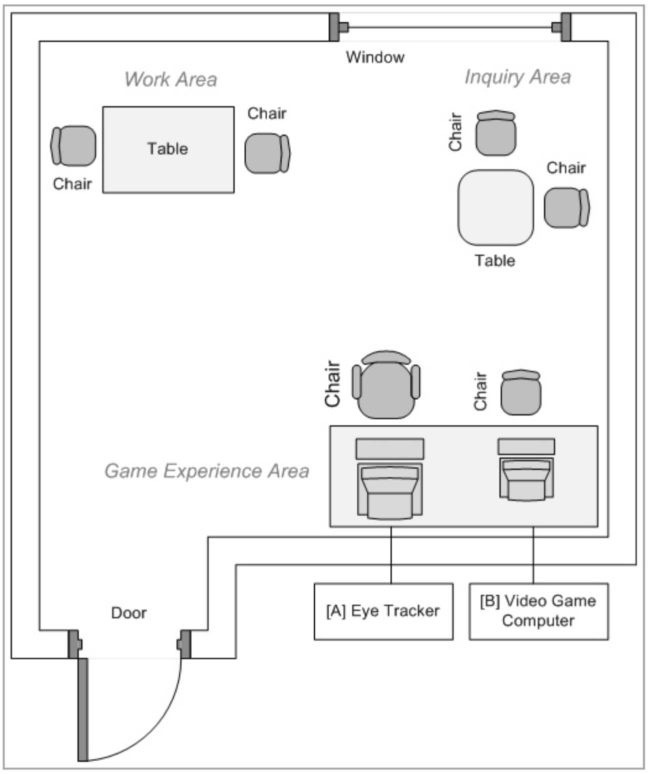


Figure 12 - Empirical study laboratory setup

The room was divided into three parts: a work area, a reunion area and the game experience area. The work area was composed of a table and a couple of chairs where the investigator could prepare the empirical study. The reunion area consisted of a small table and two chairs. This area was reserved for the second part of the empirical study, where the investigator and the participant would sit down and discuss, as mentioned above, the two tasks the participant had carried out as well as fill out the questionnaire. Finally, the game experience area was the station where the Tobii Eye tracker and stimulus (video game) computer were set up. Despite the two computers being located beside each other, the investigator would only go to the station at the beginning and end of each task, whether to set up the tasks or to terminate them. Despite the organization of the room, an informal but rigorous environment was created and preserved. The area reserved for the execution of the game experience was faced to a wall so that the participant would not divert his/her attention from the monitor; the door to the laboratory was kept closed at all times and a warning was placed on the door to inform the waiting participants to not enter the room without consent.

7.4. Technological Setup

The Tobii Studio software bundled with the Tobii Eye Tracker T120 supports various types of media and stimuli: instructions (text); images; movies; web; screen recordings; scene camera and external video.

Preliminary tests were done using the screen recording stimulus option. This attempt proved to be inadequate considering the type of media used in the study: a high computer resource consuming video game. Upon commencing the test, the screen recording option allowed the user full control of the computer while recording a person's eye movement and actions. When launching the game, the software was not capable of recording the video game being displayed on the screen at the same frame rate the game was actually being played. Therefore, the final replay of the video recorded by the software showed a reduced number of captured frames. A more extensive look at the user manual suggested the used of the external video option for a video game stimulus. Furthermore, upon reading the minimum system requirements for this option, a different computer was chosen for the setup; a computer that exceeded the minimum system requirements for both the software and the video game.

The final technological setup required the use of two computers: a host for the Tobii Studio Software and monitor (Figure 12[A]) that would receive the signal from the stimulus presentation computer (Figure 12[B]), that is, the computer running the video game. Since the host computer had to receive video input, the use of a Pinnacle Movie Box[19] was required as an intermediate in the process. The Pinnacle Movie Box's function was to capture the analog signal being sent from the stimulus computer, convert it to a digital signal, and re-send it to the host computer running the software. The technological setup can be seen in Figure 13.

[19] MovieBox DV is an analog to digital video converter.

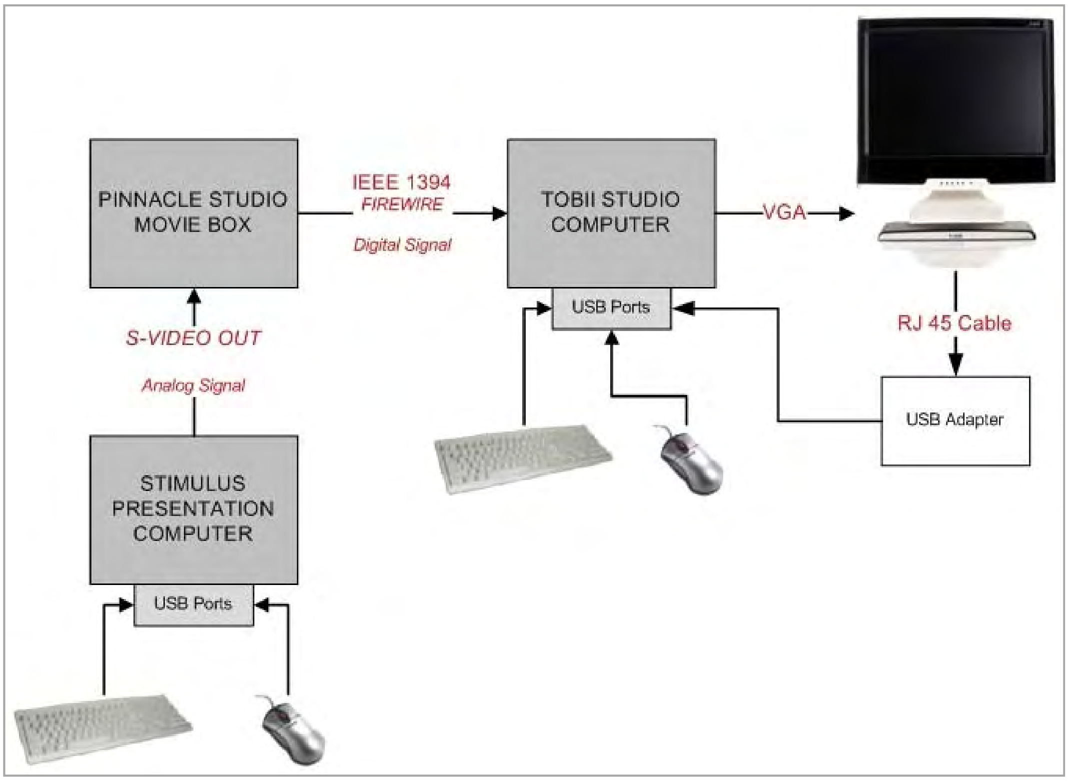


Figure 13 - Technological setup used to run Call of Duty from host computer to the Tobii Eye Tracker

Specifically, the stimulus presentation computer (module I) running the video game received input from traditional input devices (mouse and keyboard). The signal running on the stimulus computer, as mentioned above, was sent via an s-video cable to the intermediate component – the Pinnacle Studio Movie Box (module II). Here, module II would convert the analog signal that was received from the stimulus computer to a digital signal and send it, via an IEEE 1394 cable, to the host computer running the software (module III). Module III would then send the received signal via a VGA cable and display it on the eye tracker monitor. Finally, the data collected by the eye tracker would in turn be sent, via a RJ45 cable connected to the host computer using a USB 2.0 adapter, over a structured network.

7.5. Data acquiring instruments

7.5.1. Questionnaire

The questionnaire[20] the participants were asked to fill out was composed of 8 questions that explored the participants' experience as well as some of the key aspects of the game. Players' opinions on game elements that conditioned their eye movements or avatar movements as well as the efficiency of game elements were some of the core areas covered by the questionnaire.

The first question (Question 1 A) assessed, taking into account the elements listed or others the participants offered, how each of those elements played a role in where the participants looked at in the game and to what extent they influenced their eye gaze. The elements the participants were asked to consider were the

[20] For full questionnaire please consult Appendix 1 – Questionnaire used in empirical study.

following: buildings (in general); stairs (associated to buildings); balconies; windows; wall barriers; cars and trees. The second question (Question 1 B) was of similar nature. However, the main purpose was to understand how the same elements (or others mentioned by the participants) influenced their strategy in terms of avatar movement. In both the first and second question, the scale was of four possibilities: *doesn't influence; has little influence; influences; influences greatly*.

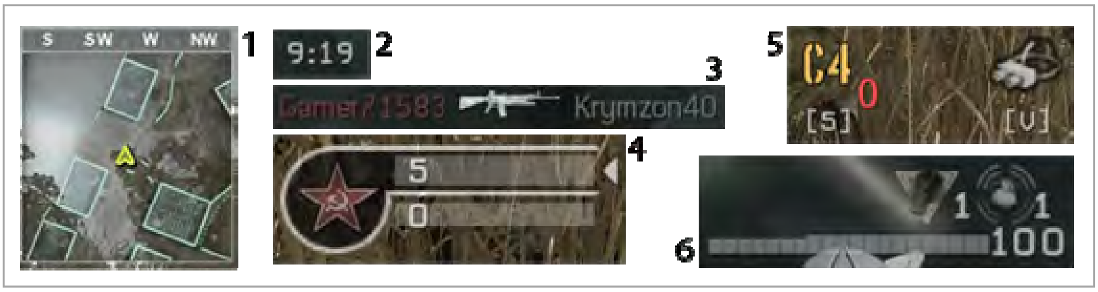


Figure 14 - Call of Duty 4: Modern Warfare interface elements: 1 - game map; 2 - time; 3 - game events; 4 - game score; 5 - special utilities; 6 - ammunition

The third question (Question 2 C) looked to understand the participants' point of view in what concerned the various elements of information present on the interface, as seen in Figure 14: game map; game events; game score; game time; special utilities and ammunition. What was asked of the participants was to discuss if they thought the iconography chosen for the mentioned elements was efficient and in fact transmitted the information it was designed to communicate. According to their answers, using the scale *not efficient, moderately efficient, efficient and very efficient*; participants were asked to discuss their thoughts, especially if having chosen not or moderately efficient. The fourth question (Question 2 D), using the same scale as in question three, assessed the participants' opinions in terms of the chosen localization of the elements on the interface. Once again, the participants were asked to discuss their opinion in terms of what they thought was wrong or could be improved if they believed one or more of the elements was not adequately placed.

The fifth (Question 3 E) and sixth questions (Question 3 F) concentrated on the game feedback. Question 3 E asked the participants if they were aware of the existence of feedback when having interacted with elements such as guns, vehicles, buildings and other avatars. Each participant was exemplified with situations of feedback returned by the mentioned elements so that they could more accurately reflect on their experience. The scale used was a simple *yes, no, I don't know*. If the participant understood the existence of feedback they were asked to answer yes; if they interacted with one of the elements and didn't notice any feedback they were asked to answer no; if they did not interact with one or more of the elements, they were asked to answer I don't know. Question 3 F focused on the efficiency of each of the elements mentioned. Participants were asked to define the feedback given by each of the elements as *not efficient, moderately efficient, efficient, very efficient* or *I don't know* if they didn't interact with one of the mentioned elements or didn't notice the feedback.

Finally, question seven (Question 4 G) asked the participants to explore their opinion on various aspects of the two tasks they had completed and consequently, the two maps played. These elements were the luminosity of the maps, the number of buildings, the diversity of the buildings, the possibility of exploring the maps, places to hide and finally, the diversity of obstacles. To wrap up, question eight (Question 4 H) allowed the participant to comment on the experience as a whole as well as offer positive and negative opinions. Furthermore, they were asked to discuss possible suggestions for the game taking into account their experience with the two tasks they carried out as well as experience with similar games of the same genre.

7.5.2. Tobii Eye Tracker

The Tobii Eye Tracker, present in Figure 15, and corresponding software, was the second instrument used to collect data. While the questionnaires provided information and personal opinions related to the participants' game experiences, the eye tracker provided concrete visual information related to the participants' eye movements during the two tasks that were carried out.

Figure 15 - Front view of the Tobii T120 Eye Tracker [retrieved from: http://www.tobii.com]

The *setup* of a new project using the Tobii Software is of simple nature. Upon launching the software and choosing to create a new project, the following step is providing the project a new name and an author (if desired). Then, depending on the number of tests associated to a project, each test must be given a name. Therefore, to exemplify, a name for a new project with two tests could be "Web Usability Study" and the name of the tests could be "Yahoo homepage" and "Google homepage".

Once these steps have been completed, the user is in the software *environment* where he/she can run the tests and manipulate data through the use of the options present on the three panes of the software.

As mentioned earlier, Tobii supports the recording of various stimuli and media as well as the combination of several of these media. The setup of the stimuli or media is done on the *Design and Record* pane as can be seen in Figure 16. Figure 16 demonstrates a test with only one stimulus – an external recording.

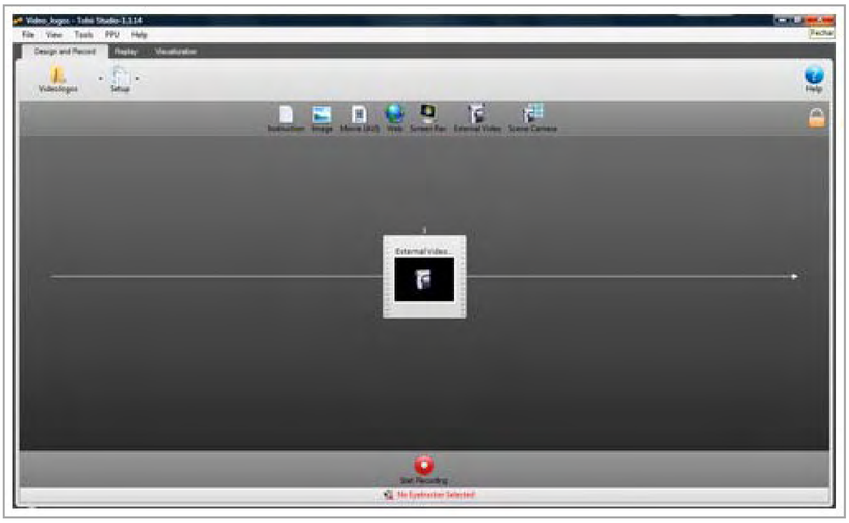


Figure 16 - Tobii Studio Software: Design and Record pane

Figure 17 - Tobii Studio Software: Replay pane

After a test has been completed, the visual data can be seen and further analysed through the use of the Replay and Visualization panes. The Replay pane – Figure 17 – shows a list of the various recordings associated to a test (on the left). For every recording there is a video which can be seen in the centre and controlled using the buttons near the timeline. Here, it is also possible to create markers to register and define points of interest. For some media, segmenting video is necessary and that is also done in the Replay pane. Furthermore, images and video can also be exported for exterior analysis through the use of the Export option also found on this pane.

Finally, in the Visualization pane as seen in Figure 18, the user can access the visualization tools the software offers: Gaze plot, Heat Map, Cluster, Bee Swarm, AOI (Area of Interest) tools and Statistics. Figure 17 presents data using the heat map tool. However, not all of these tools are available for all of the recorded stimuli and the use of some requires, as mentioned, segmentation of the acquired data.

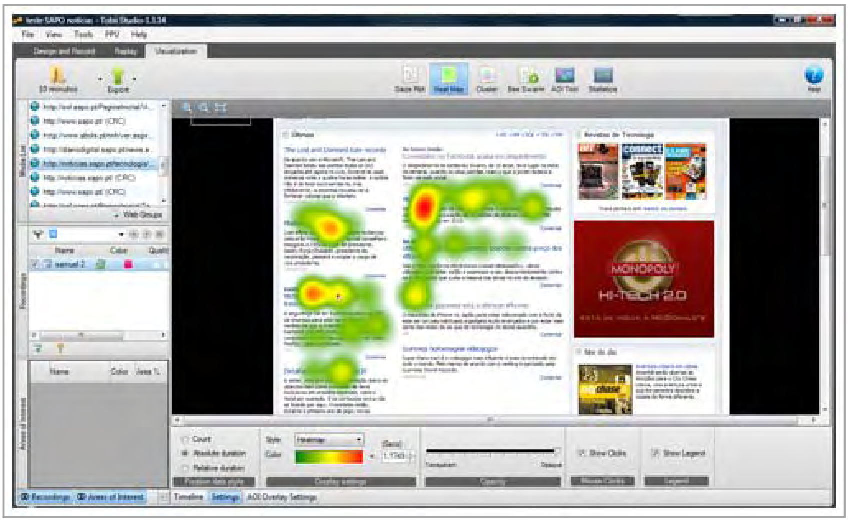


Figure 18 - Tobii Studio Software: Visualization pane and visualization tools

Having taken a look at the basic setup of the software, we now look at how the software was used to collect visualization data.

As seen before in the characterization of the study protocol, each two-task session with each participant included various steps: defining a participants' ID, selecting the participants' game experience and genre, and finally associating each of the two tasks to the participants (*Jn_t1 & t2*; in which n represents the participant ID and t represents task 1 and task 2). As each participant completed their tasks, a list of the various recordings was located (in alphabetical order), as mentioned, in the Replay pane.

Each of the recordings was presented as a video and was associated to a timeline. Like traditional video and similarly to what can be found in video editors, the recording could also be controlled: it could be played, stopped, paused, forwarded, rewound and controlled manually with a slider. As the recording is a video, the data that is at hand is the players' movements while playing, as well as the places and objects looked at.

Understanding each of the players' choices in movement as well as what they looked at was necessary to comprehend exactly what elements of the map appealed more to the player; revealing therefore, areas of greater interest and areas with less interest. The question that consequently materialized was: *how to represent these areas of interest?* The logical choice was, and considering the tools present in the Tobii Studio software, a heat map. A heat map can be defined as, taking into account various authors' definitions, "a map or a data visualization that uses colour or some other feature to represent data values (…) (Heat Map Learning Centre, 2008) & (Fry, 2004).

The heat map is one of the most valuable tools the software offers. However, bearing in mind the tri-dimensional nature of the video game; analyzing points of interest using this tool introduced some complications that traditionally do not occur with *static* media such as web sites. For that reason, it was imperative to find an alternative solution that could replace the traditional heat map but that could, simultaneously, represent points of interest and data values.

For this part of the study and, contrary to what was done with the questionnaires, only the hardcore gamers that participated in the study were considered. The reason behind this choice was the fact that inexperienced and casual players do not have as much experience – when compared to hardcore gamers – with this type of video game. Therefore, it is believed that their behaviour in the game is, in most cases, based on random choices and not the result of logical rationalizations during the tasks. Furthermore, studies have shown that game experience does play a role in visual search and in object localization. Green and Bavelier (Bavelier & Green, 2003) showed that players with greater experience in action video games have a greater attentional capacity and control of selective attention. Nonetheless, a study by Castel, Pratt and Drummond (Castel, Pratt, & Drummond, 2005) suggested, and in some way diverging from Green and Bavelier's work, that different experience groups use similar mechanisms to control their visual attention but that experienced gamers are more rapid at executing responses in their visual environment. In addition, and as will be explained later on, only twelve of the thirteen hardcore participants were used in this part of the study. Furthermore, considering once again this particular part of the study, only one of the tasks was explored and consequently, only one map and game mode was used: the *Domination* mode played on the *Strike* map, as seen in Figure 19.

Figure 19 - 2D representation of the Strike map

As refereed earlier, each task was played using a specific game mode. *Free-for-All* allowed the player to roam around the map freely while *Domination* had specific objectives: attack flags in enemy possession and defend those in the player's team possession. Considering the player had the objective of attacking and defending flags, it was believed that his choices in avatar movement and the directions taken would be the result of logical choices considering the placement of the flags on the map. For this reason, it was felt that the *Domination* mode would be propitious for a richer gathering of data for the elaboration of the intended heat map.

To elaborate this alternative heat map, it was first necessary to map out the participants' courses of action. To accomplish this, a two dimensional representation of the *Strike* map was drawn which resulted in the map seen in Figure 20. The white area enclosed by the exterior border are regions where the player can move his avatar; the areas with diagonal lines in blue represent buildings that can't be accessed while areas stroked out with red are building that are accessible and can be explored. Furthermore, most of the area that forms the exterior border of the map is made of buildings that are inaccessible to the players. Also found on the map are three green stars which represent the location of the flags during the game. On the same figure, a detailed view of the icon representing the flag can be seen.

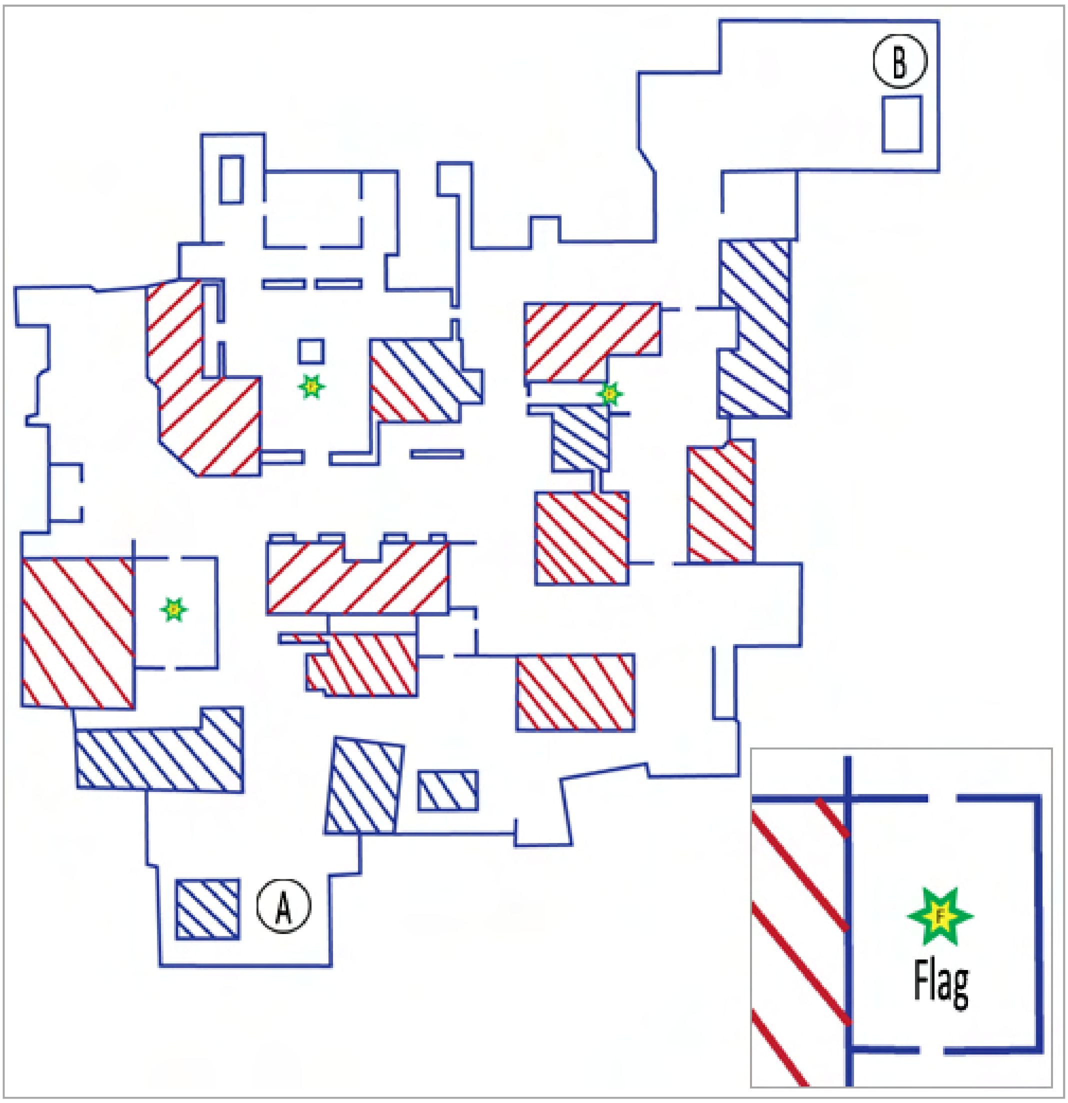


Figure 20 - Illustrated view of the Strike map with detailed view of flag (bottom corner)

In the *Domination* game mode and on the presented map, the flags were always positioned in the same place; a factor that benefited this particular part of the study as it always created the same game conditions for each of the participants. The only difference that occurred between the various participants is the place where they began the game: choosing one team resulted in beginning the game in the area found in the bottom-left corner – represented with the letter A – whereas choosing the other team implied beginning the game in the top-right corner of the map – represented with the letter B.

Taking into account that the tasks were played during 5 minutes and, considering that the Tobii Eye Tracker and software can record to the thousandth of a second, it was felt that marking every second would result in excessive information to analyse. As a result, a *sampling* strategy was adopted, and therefore, it was decided that inserting markers on the timeline – on average – every 5 seconds, would be sufficient to build the heat map. However, this choice did not imply that a thorough view of each of the videos would be discarded. Although the average marker was placed every 5 seconds, if during the time span that lasted from *t*[x] and *t*[y] (x and y representing two consecutive moments of interest), a visualization of interest was observed, that moment was marked as well. The same occurred for moments in which the player remained fixed on a specific spot of the game map (e.g. while firing upon an enemy or while waiting for a complicated situation to dissipate). In this situation, the next sample was taken at the next most significant moment on the timeline. Therefore, with these ideas at hand, and considering that each participant had a different interpretation of the task, their in-game situation and the objectives at hand; each timeline was different and resulted from the conjunction of the mentioned factors.

To be able to elaborate the intended heat map, placing on the map a simple dot representing the player's position for every sample was not sufficient. For each of the samples at hand and, for every participant considered, there were various elements to be evaluated: where on the map the player was, the player's field of view, the elements (e.g. cars, trees, doors, avatars) in that field of view and finally, what exactly the player was looking at. In other words, what is being analysed is the players' Point of Regard, as mentioned previously in Section 3.1.4.

To represent these elements, a symbol was used to reproduce the player's position and what he/she was looking at.

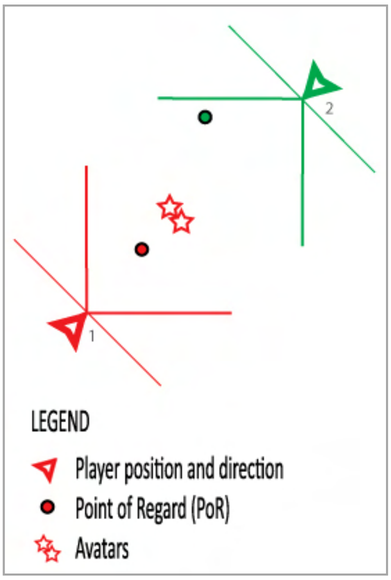


Figure 21 - Elements used to represent player position [1 – looking in the middle; 2 – looking to the right]

Figure 22 - Representation of player looking to middle of the screen [as seen in (1) in Figure 20]

As can be seen in Figure 21, a player's position on the map is represented by a triangular shape whereas the two lines that move outwards to the front – forming a 90º angle – represent the player's range of view. After some calculations, the player's angle of view was determined to be of 90º, represented as such in the shape used. The circular shape outlined with black also found on the same figure represents the actual point where the player was looking at in the map. The shape was placed as close as possible to the in-game element (whether it be a tree, an avatar, a car or others) the player was looking at. Finally, if enemies or team-mates were present in the player's line of sight, stars, as seen in Figure 21(1), were used to represent these. If the player was looking at a different element, then a label would be placed at that point on the map. Also, a number was placed by each of these representations so that the participants' movements during the task had a sequence and were understood.

Figure 23 - Representation of player looking to the right of the screen [as seen in (2) in Figure 20]

Therefore, and for each of the participants' samples, a representation of what the player saw at that moment was placed on a separate layer. This was done for the twelve participants used in this part of the study. Representations of two distinct players' routes during the task can be seen in Figure 24 and Figure 25[21]. In Figure 24, the participant explored central areas to the right whereas the participant in Figure 25 focused on exploring and playing the left side of the map.

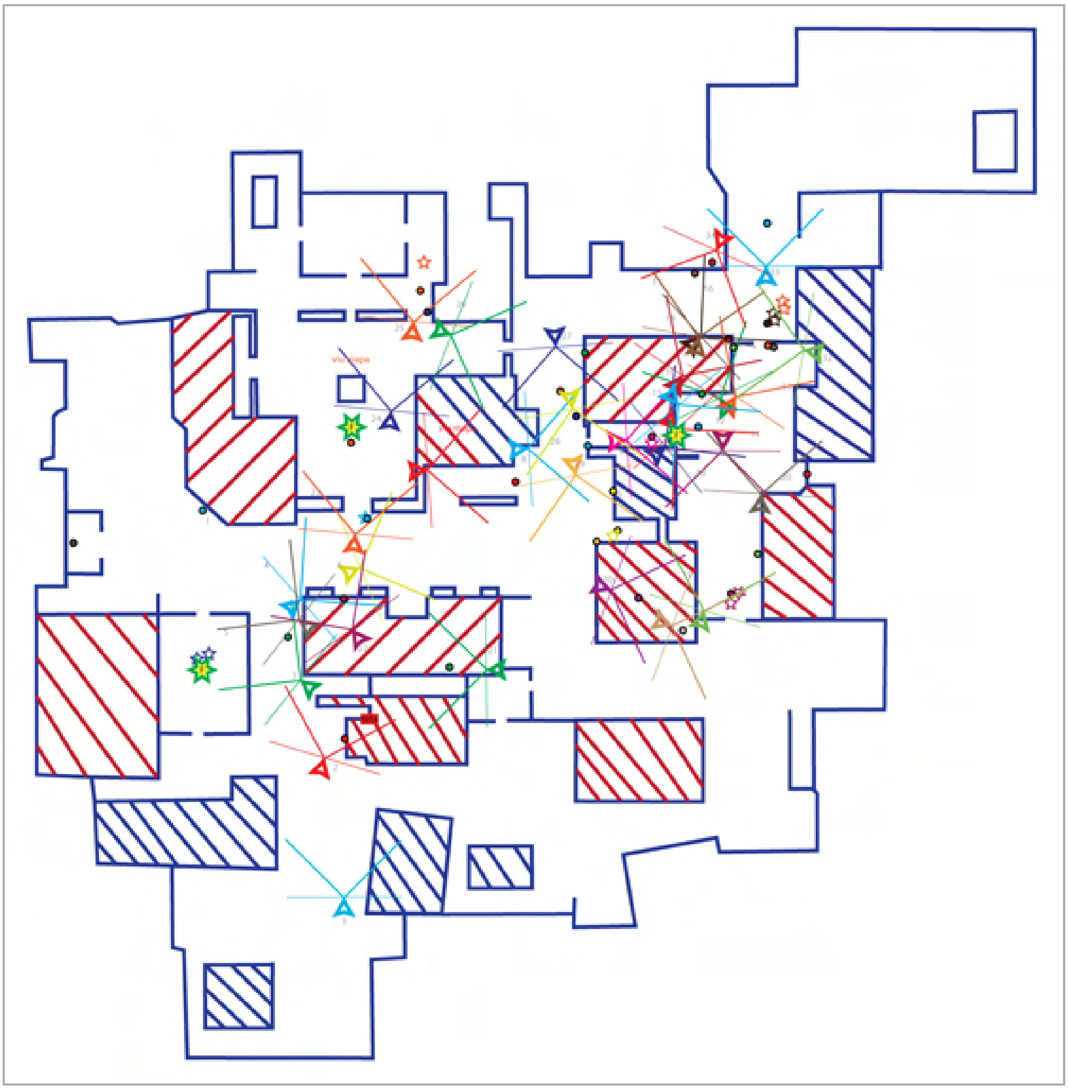


Figure 24 - Example of one participant's in-game movements. This representation shows a tendency for the player to explore the central areas of the map.

[21] For complete selection of all players' movement representations consult Appendix 3 – Player in-game movements.

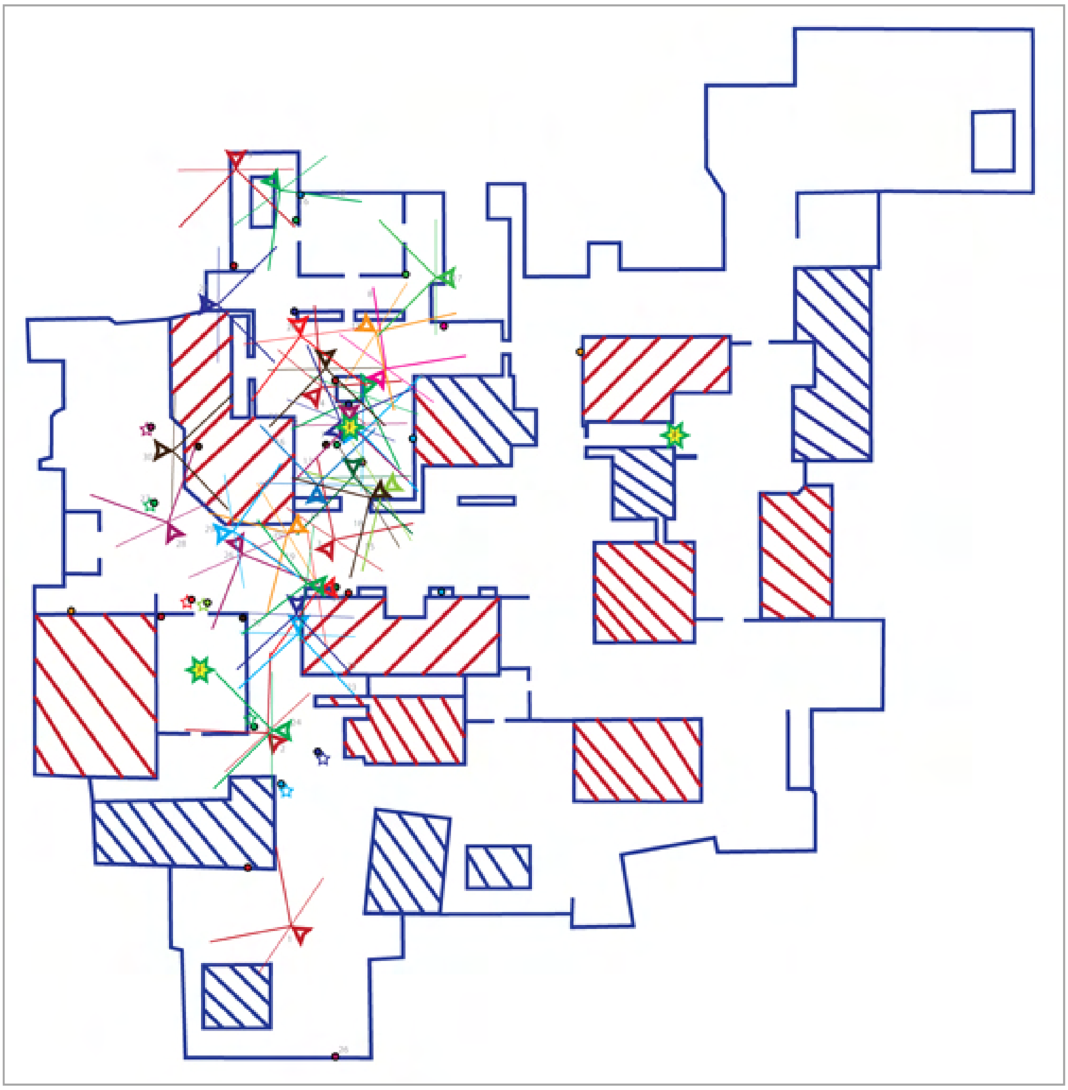


Figure 25 - Example of one participant's in-game movements. This representation shows a tendency for the player to explore the left side of the map.

Once all twelve representations were completed, the next step was building the intended heat map. As seen earlier, a heat map is a representation, using colours, of specific data values. The Tobii Studio software can generate three different types of heat maps: count heat map, absolute duration heat map and a relative duration heat map. For the present study, the count heat map – that shows the accumulated number of fixations from a number of selected people – was the model to be constructed. Therefore, the differences in colour present on the built heat map would represent the sum of the number of times that specific area was visualized by the players and not the time (in duration) it was looked at.

Building the heat map required choosing a colour lookup table with a colour scale that would represent pre-determined data values. Many heat maps use only three colours – traditionally green, yellow and red –, but for the presented study, the *traditional* colour scale did not seem adequate. The colour green, which would correspond to a smaller number of visualizations, did not seem to fit the purpose of the intended representation due to the high contrast of the colour used to represent low values. Therefore, darker colours and shades of blue were selected to represent lower data values whereas the black background represented a 0 value of intensity (views). Furthermore, the darker colours and shades of blue naturally contrasted with the orange and red colours representing a greater number of views. Bearing that in mind, the choice fell upon the colours that compose the visible spectrum, as seen in Figure 1Figure 26.

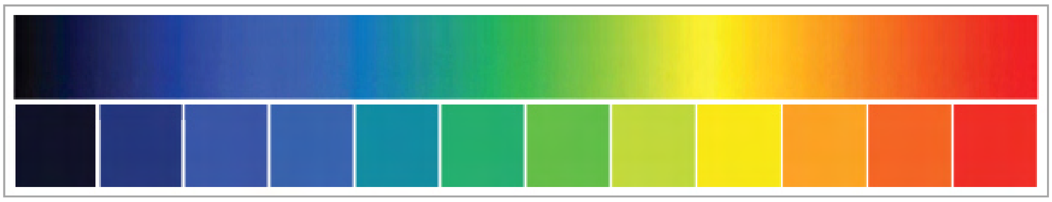


Figure 26 – Colour scale (based on the visible spectrum) used to build heat map and the twelve colours of the palette used for the colour lookup table.

The traditional colours of the spectrum are six (as the colour indigo is not always considered): violet, blue, green, yellow, orange and red. Nonetheless, the presented colour spectrum was divided into twelve parts, and consequently twelve different colours were extracted, resulting in the colour lookup table visible in Figure 26. With a greater number of colours in the lookup table, player activity and the distribution of visualizations could be more meticulously represented. Although the defined lookup table could be used for any number of participants; to create a more linear representation of the players' views on any quadrate of the map, it was felt that using 12 participants to correspond to the 12 colours of the lookup table would be a more favourable approach. This choice resulted in having to renounce to one of the hardcore players' results. To make sure the correct participant was excluded, the hardcore players' in-game performances as well as questionnaires were analysed and the participant that less impressed was not used.

The following step was creating an object that could be *coloured* (or codified) according to the number of times a specific area was visualized. Therefore, the map seen earlier in Figure 20 was enlarged and a grid with 50x50 pixel quadrates was placed over it as can be seen in Figure 27. This elaborated grid allowed for all the individual cells to be manipulated as needed and therefore, coloured with the desired colour from the lookup table. With the grid at hand, it was then necessary to analyse – one participant at a time – the various markers registered so that the areas of the game that were in their line of sight for the various samples taken were represented on the corresponding illustrated map.

All the quadrates in the areas that were seen by the first participant were filled with the first colour of the lookup table visible in Figure 26. However, it must be noted that, for example, if a wall was in the player's range of view, none of the quadrates beyond that equivalent place on the map were codified. This is to say that the colouring of the grid wasn't carried out in a linear form and that questions such as the one presented were always taken into consideration. After analyzing the first participant's in-game visual behaviour, the second participant's visual field for the selected samples was then represented. If for a particular sample, the second participant had in his line of sight areas that had previously been seen by player one, then that same area was filled in with the second colour of the lookup table (Figure 26). However, if the area the player was looking at had not yet been seen, it was filled with the first colour. Therefore, for example, when analyzing the performance of player 6, the colour used to codify the quadrates was not always the 6th colour of the palette. That colour was only to be used if the quadrate(s) in consideration had already been seen by the previous 5 participants. If the quadrate had only been seen by two participants, then the colour used to codify that quadrate was the third colour of the lookup table. The twelve colours of the lookup table functioned, therefore, as a representation of a visualization count and the use of the twelve colours assured that if all twelve participants looked at the same area, this occurrence would be distinguished from an area that was only seen by six.

This process was then repeated for all twelve of the participants. Therefore, and to better understand the complexity of the process, areas of the map remained black if no participants looked at an area and were red – the last colour of the palette – if all twelve participants looked at that area, at least once.

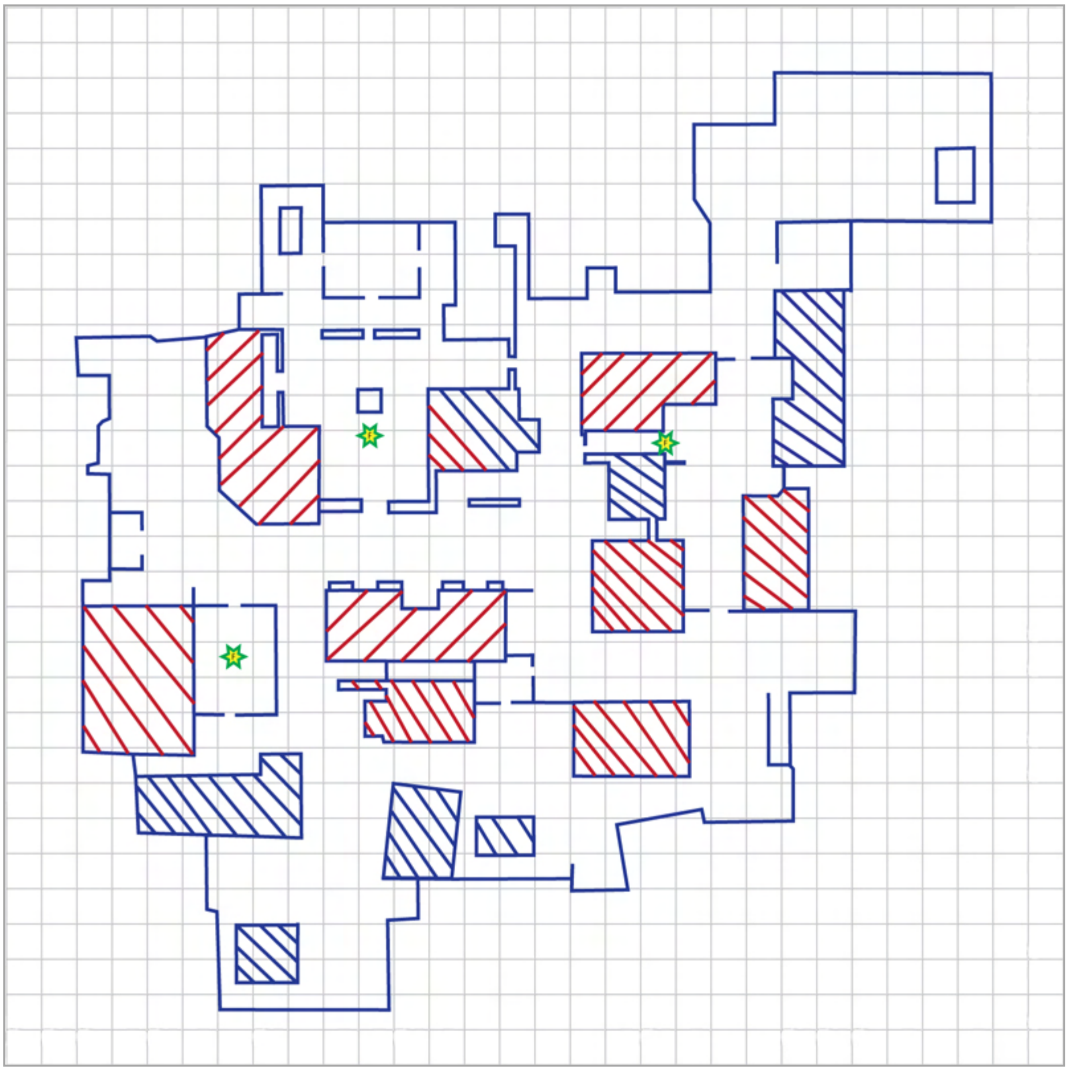


Figure 27 - Illustrated view of the Strike map with overlapping grid

This concludes the description of the process and methodology that led to the elaboration of the heat maps, the most visible result of the differences in player visual behaviour.

8. Data Analysis & Results

Having explored the instruments used to collect data for the present case study, the following section will now address the results obtained via those instruments.

8.1. Questionnaire data presentation

The acquired results will be presented in the order they appeared on the questionnaire[22] and always beginning with the inexperienced participants, followed by the casual game players and finally, the hardcore gamers.

The first question (Question 1 A) of the questionnaire (as seen in section 7.5.1) focused on, taking into account pre-determined elements or others suggested by the participant, how each of those elements played a role in where the participant looked at in the game and to what extent they influenced their eye gaze.

To commence, and considering first the **inexperienced players** group composed of 12 participants, the compiled table of results indicates some distribution among all of the possible answers. Nonetheless, and as will be seen in the other questions, a greater importance will be paid to those results in which the majority of the players agreed on the same answer. With that in mind; 58% of the inexperienced participants indicated that buildings in general influenced their eye movement; 50% answered that balconies did not influence at all eye movement and finally; 50% answered that trees had little influence on their eye movement. Having asked the players to identify other elements that influenced their eye gaze, inexperienced participants identified elements such as places where there was *action*, *water fountains*, *fire and smoke* as well as *explosions*.

[22] For full questionnaire please consult Appendix 1 – Questionnaire used in empirical study.

Moving on to the second question (Question 1 B), participants were asked to what extent the listed game elements influenced their choices in the movements they took with their avatars.

The resulting table of answers demonstrated that, once again, there was some distribution of the participant's answers. 67% of the participants – two thirds, a significant result – found that buildings in general influenced greatly their movements whereas the same number indicated, however, that windows had no influence over their choices in avatar movement; 58% of participants indicated that both balconies and trees had no influence over their movements and finally; 50% answered that cars had little influence on their choices in avatar movement. Other elements suggested by the participants as having influence on their movement choices include areas where there was *gun fire*, *statues* (located inside the map) and *low obstacles*.

Moving on to the **casual players**, 16 was the number of participants that formed this group. In what concerns Question 1 A, 50% of the participants indicated that buildings in general had a great influence on their eye gaze; 50% of the participants also answered that both balconies and walls influenced their eye gaze and finally; 56% said that trees had little influence on their eye gaze. Other elements mentioned by casual players as having an impact on their eye gaze were *building doors* (as they were places where the player could hide or where the enemy could appear); *barrels*; areas where there was *gun fire* and finally, one player mentioned a *helicopter* (accessible when a player kills an enemy a specific number of times).

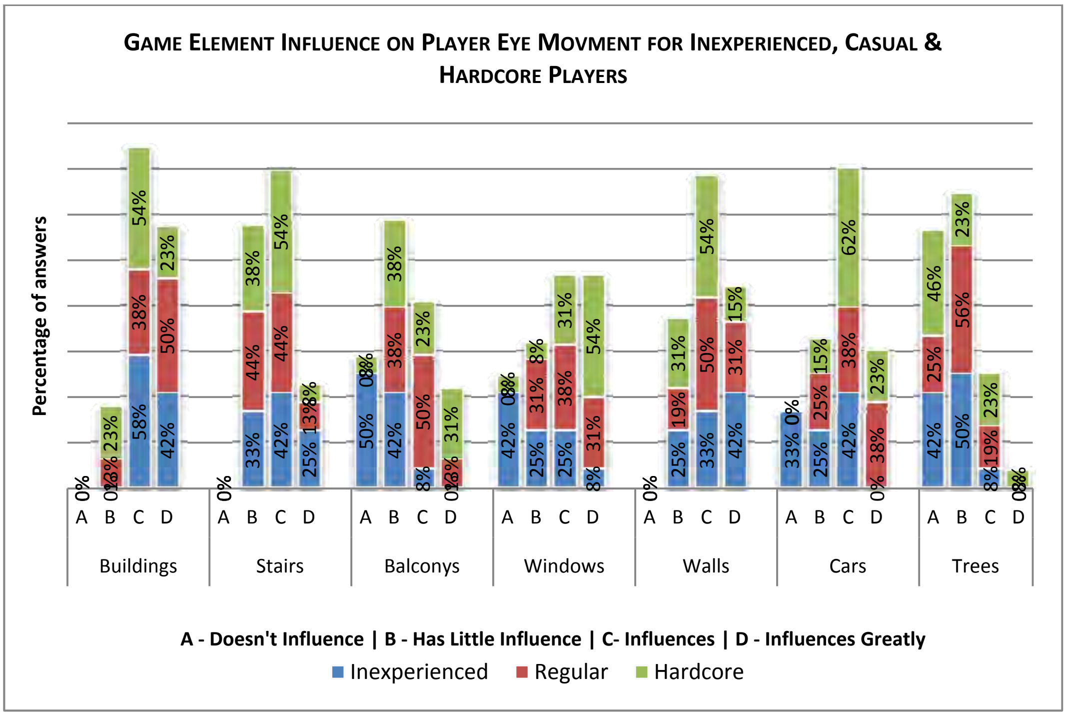
In Question 1 B, a greater harmony among the participants was visible as on 6 occasions, 50% or more of the participants shared a similar answer, including one with a consensus of 75%. Specifically, 75% of the casual players indicated that buildings in general influenced their choices in avatar movements; 69% answered that balconies had little influence on their movements; 63% answered that stairs influenced their movements; 56% believed that walls had a big influence on their movements whereas the same number indicated that trees had little influence. Finally, 50% of the casual players indicated that windows had little influence on their avatar movements. Other elements mentioned, similarly to Question 1 A, were the *building doors* as they were places where one could hide out and keep safe from enemies.

Moving on to the last group of participants, the experienced and therefore ***hardcore* gamers**; this group was composed of 13 participants. In Question 1 A, a first look at the results shows that clearly many of the mentioned elements had at least a normal influence on the hardcore players' eye gaze. This was true in 5 cases, where 50% or more of the participants shared a similar view on the influence of an element over their eye movement. Specifically, in 3 of the elements – buildings, stairs and walls – 54% of the *hardcore* gamers indicated that these influenced their eye gaze. However, the same number also indicated that windows greatly influenced their eye movements. Finally, the element *cars* received 62% of the players' answers, indicating that it had an influence on their eye gaze. Some of the other elements mentioned by the experienced players were *barrels*, *shadows* (of various elements) and also the *sound of the gun fire* as it alerts the player he is near an action zone and therefore could stumble upon an enemy.

Moving on to Question 1 B, the number of occurrences in which there was a majority consensus among hardcore players was not as evident as in Question 1 A. Nonetheless, 62% of the hardcore players believed that buildings in general greatly influenced avatar movement; the same percentage indicated that stairs influenced their movement choices and finally; 54% answered that windows once again had influence on the way they move their avatar. In this question, no other elements were suggested as having some influence on the players' choices of movement.

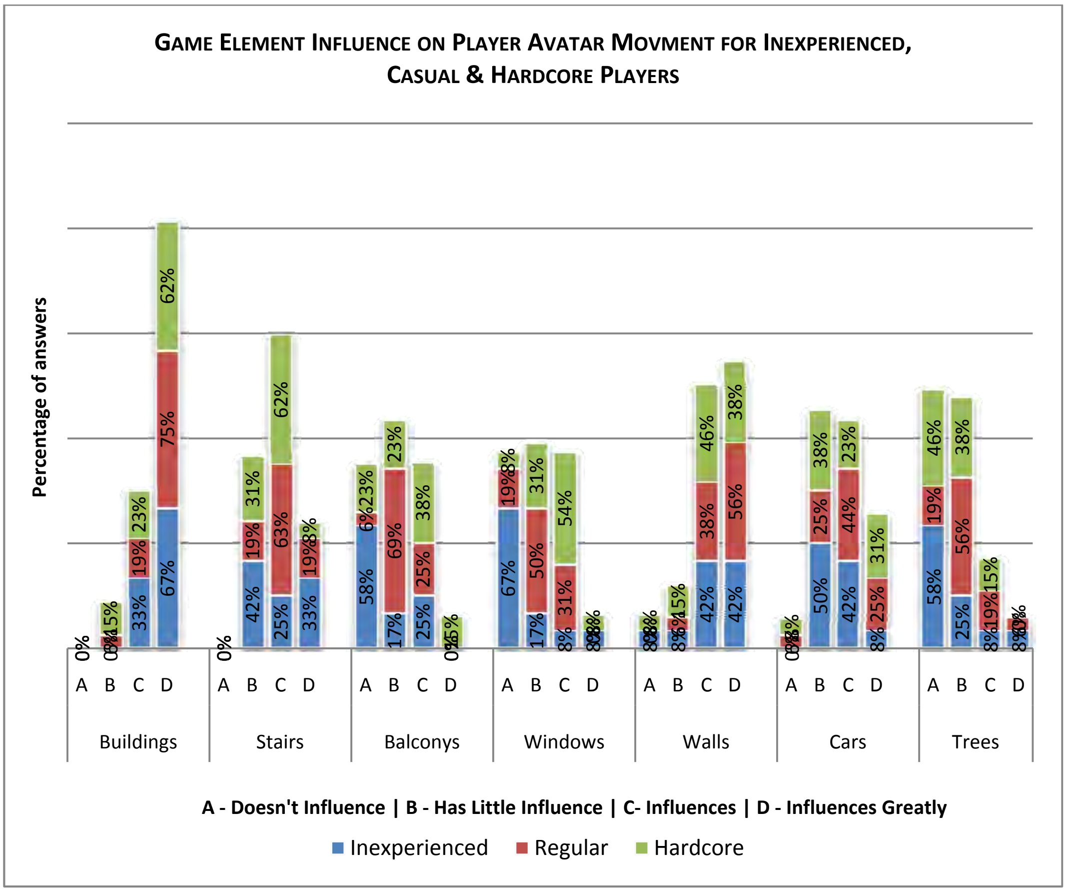
Taking a look at the general picture and comparing the results acquired from the inexperienced, casual and hardcore gamers; it is visible that the consensus among these three groups was reduced. No occurrences of

50% or more of the players (of all three groups) sharing the same opinion over the influence of one the elements were verified. However, three occurrences of at least two groups agreeing in consensus were verified. First, 58% of inexperienced players and 54% of hardcore players indicated that the buildings element influenced their eye movement; second, 50% of casual players and 54% of hardcore players answered that walls influence their eye gaze. Finally, the third occurrence resulted in 50% of inexperienced players and 56% of casual players indicating that trees had little influence on eye movement. In addition, for three of the seven elements – buildings, stairs and walls – none of the players from the three groups indicated that either one of these elements had no influence over their eye movement. Taking a look at the mentioned results, a common association between all of them was that they all converged on the positive answers: *influences* and *influences greatly*. The distribution of these results can be seen in Graph 1.



Graph 1 - Game element influence on Inexperienced, Casual and Hardcore players' eye movements (Question 1 A)

Looking at Question 1 B and contrary to what occurred with Question 1 A, one occurrence of all three player groups sharing a majority of opinion was verified. This occurred for the element buildings where 67% of inexperienced players, 75% of casual players and 62% of hardcore players indicated that buildings influenced greatly their choices in movement. Furthermore, on one occasion, two of the groups shared a majority in opinion: 63% of casual players and 62% of hardcore players indicated that stairs influenced greatly their choices in player movement. Despite this result, the remaining distribution of answers resulted in, once again, a reduced consensus among the participants. Finally, and as occurred in the previous question, on two occasions, for two elements - buildings and stairs - none of the players from the three groups indicated that either of the elements at hand had no influence over their player movement choices. Furthermore, and as indicated in Question 1 A, the consensus that occurred between the groups on both occasions was for the positive answers: *influences* and *influences greatly*. These results can be seen in Graph 2.



Graph 2 - Game element influence on Inexperienced, Casual and Hardcore players' in-game movement choices (Question 1 B)

Moving on to the results of the third and fourth questions (Question 2 C) and (Question 2 D), the same approach will be used to analyse the results. Recapping both questions (as seen in section 7.5.1), Question 2 C asked the participants to analyse various elements of information present on the game interface: *the game map*; *game events*; *game score*; *game time*; *special utilities and ammunition*. Question 2 D, however, assessed the participants' opinions in terms of the chosen localization on the interface for the listed elements.

Taking a look at the **inexperienced participants'** answers for Question 2 C, various occurrences of an element receiving 50% or more of the participants' answers were registered as well as one having received more than three quarters of the answers. 83% of the inexperienced players indicated that the utilities *iconography* was efficient; 67% of the participants indicated that the game map was very efficient whereas the same number said that the ammunition icon was efficient. Furthermore, 58% of the participants indicated that both game events and game points were efficient. Finally, 50% answered that the time iconography was efficient. It must also be mentioned that none of the inexperienced players but one found that the interface elements were not efficient. The only exception was one indication that the game events were not efficient.

Moving on to Question 2 D, once again, 6 occurrences of 50% or more of the participants' answers coinciding were registered. 92% answered that the game map was very efficiently placed on the game interface; 75% believed that both the points and the utilities were efficiently located; 67% answered that the ammunition icon was efficiently placed whereas 58% believed that the events iconography had an efficient placement on the interface. Finally, 50% believed that the time icon's localization was slightly efficient. Similarly to what was verified in Question 2 C, none of the inexperienced players but one indicated that the localization of the interface elements were not efficient. The element mentioned was once again the game events. This double occurrence was the answer of the same player, player J10.

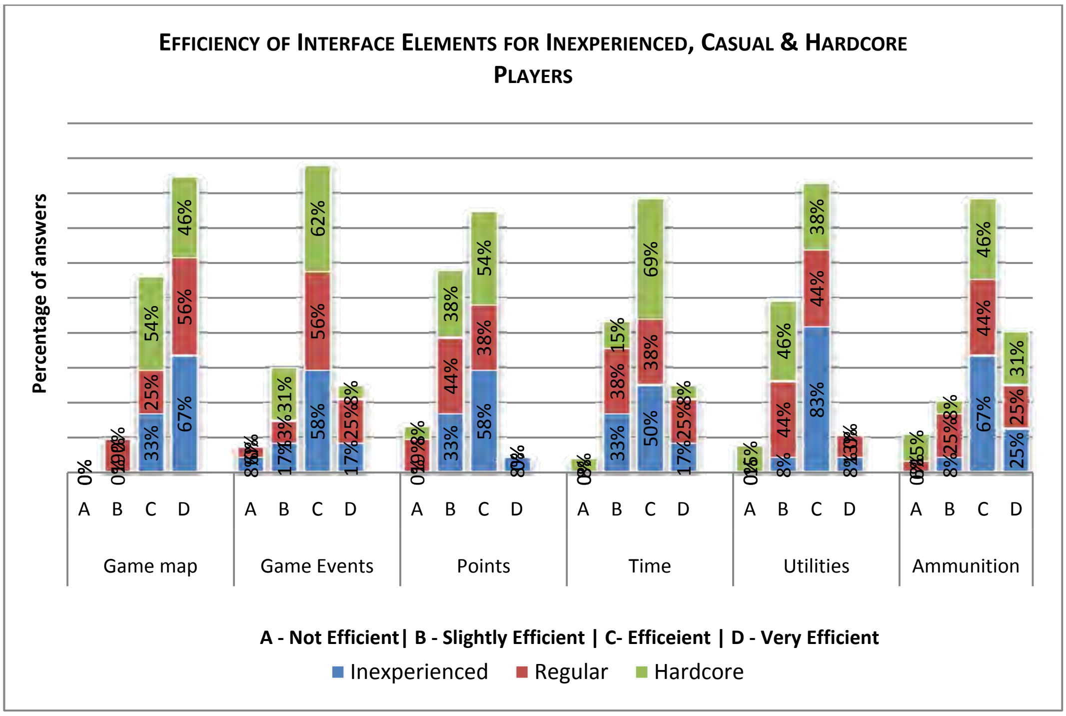
As for the **casual game players**, and returning to Question 2 C; the distribution of the answers indicates a smaller consensus among the 16 casual players. Of the possible distribution of answers, only two entries received 50% or more of the participants' answers. 56% found that the game map iconography was very efficient; furthermore, the same number indicated that the events icon was efficient. There were, however, twelve occurrences in which at least one fourth (between 25 and 50%) of the participants' answers coincided.

Considering now Question 2 D for the casual players, there were 6 occurrences where at least 50% of the players shared the same opinion. 69% of the players indicated that the game map's localization on the interface was very efficient; the same percentage also believed that both the points and the utilities were efficiently located. In addition, 63%, 56% and 50% indicated that the events, ammunition and the time, respectively, were efficiently located on the game interface.

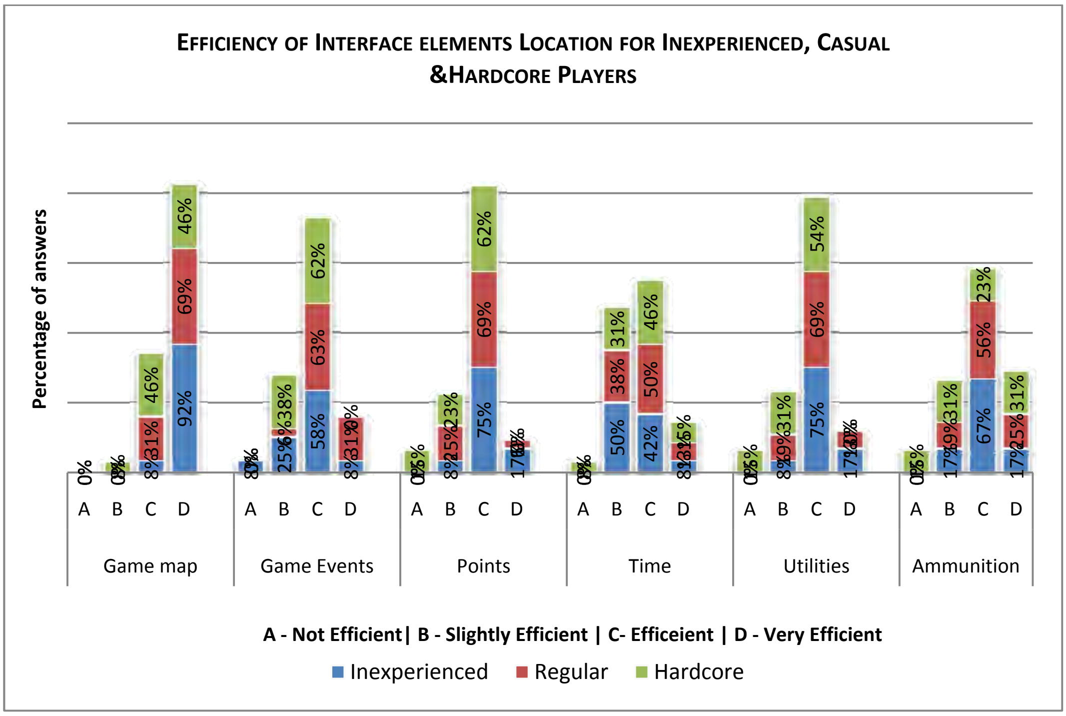
Looking at the **hardcore players'** answers, in what concerns Question 2 C, similarly to what occurred with inexperienced players, there was a greater consensus between the answers of hardcore players. 69% indicated that the time icon was efficient; 62% believed that the events iconography was efficient and finally; 54% believed that both the game map and the points icon were efficient.

Moving on to Question 2 D, the hardcore players' answers resulted in 3 occurrences in which 50% or more of the participants agreed over the efficiency of an element. 62% indicated that the game events and points localization on the game interface was efficient whereas 54% answered that the utilities icon was efficiently placed on the interface. However, there were another 8 occurrences that resulted in a consensus of at least 25% of the participants' answers.

Taking a look at the general picture of all the participants' results in what regards Question 2 C, one occurrence of 50% or more of the players of all three groups sharing a common answer was verified. Furthermore, three occurrences of 50% or more of the players of two groups were also acquired. In what concerns the first occurrence; 58% of inexperienced players, 56% of casual players and 62% of hardcore players indicated that the game events icon was efficient. As for the remaining occurrences, 67% of inexperienced players and 56% of casual players answered that the game map was very efficient; 58% and 54% of inexperienced and hardcore players, respectively, indicated that the points icon was efficient. Finally; 50% of inexperienced players and 69% of hardcore players indicated that the iconography used for the time element was efficient. As mentioned in the global analysis of the previous questions, on one occasion, none of the participants from any of the three groups indicated that the iconography for the map element was not efficient. As occurred for both questions 1 A and 1 B, the consensus that occurred between the groups was, once again, for the positive answers: *efficient* and *very efficient*. These values can be seen in Graph 3.



Graph 3 – Efficiency of interface elements for Inexperienced, Casual and Hardcore Players (Question 2 C)



Graph 4 – Efficiency of interface elements' position on the screen for Inexperienced, Casual and Hardcore Players (Question 2 D)

Moving on to the global analysis of Question 2 D; the acquired answers resulted in 3 occurrences of 50% or more of the players (of all three groups) sharing a similar opinion for one of the elements at hand. First, 58%, 63% and 62% of inexperienced, casual and hardcore players, respectively, indicated that the game events icon was efficiently located on the game interface. Secondly, 75% of inexperienced players, 69 % of casual players and 62% of hardcore players answered that the points iconography was efficiently placed on the interface. Finally, 75% of inexperience players, 69% of casual players and 54% of hardcore players answered that the utilities icon was efficiently placed. Furthermore, on two occasions, 50% or more of the players of two of the groups shared a similar answer. 92% and 69% of inexperienced and casual players, respectively, indicated that the game map was very efficiently located on the game interface. Finally, 67% of inexperienced players and 56% of casual players indicated that the ammunition icon was efficiently placed on the screen. Taking a look at these results, once more, the common link between all of them was that they all converged on the positive answers: *efficient* and *very efficient*. These values can be seen in Graph 4.

The fifth (Question 3 E) and sixth (Question 3 F) questions (as seen in section 7.5.1) focused on the game feedback. In Question 3 E, participants were asked to indicate if they had perceived the existence of feedback when interacting with the four listed elements: *weapons*, *vehicles*, *buildings* and *avatars*. Question 3 F inquired, however, on the efficiency of the feedback. That is, bearing in mind the type of feedback generated by the game, how efficient did the participants find it to be?

Beginning once again with the **inexperienced players**, and as will be seen with almost all the other players, these participants showed a great tendency to have perceived the feedback in Question 3 E. All four elements listed received at least 50% of the positive answers: 67%, 58%, 75% and 92% said yes to having perceived feedback from the weapons, vehicles, buildings and avatars, respectively. Of the possible answers, only 6 were relative to the *don't know* option.

As for Question 3 F, once again the tendency was favourable to the positive answers in terms of the feedback efficiency. Although only two occurrences of 50% or more of inexperienced players agreeing on one of the answers were registered, the remaining distribution indicated that the element feedback was either efficient or very efficient. 50% and 58% of the inexperienced players indicated that both vehicles and building feedback was efficient. Furthermore, 42% indicated avatar feedback as being efficient. There were also 4 occurrences of 33% – a third of the inexperienced participants – of players coinciding on their answers. Considering the total number of possible answers, 8 were relative to *not knowing*.

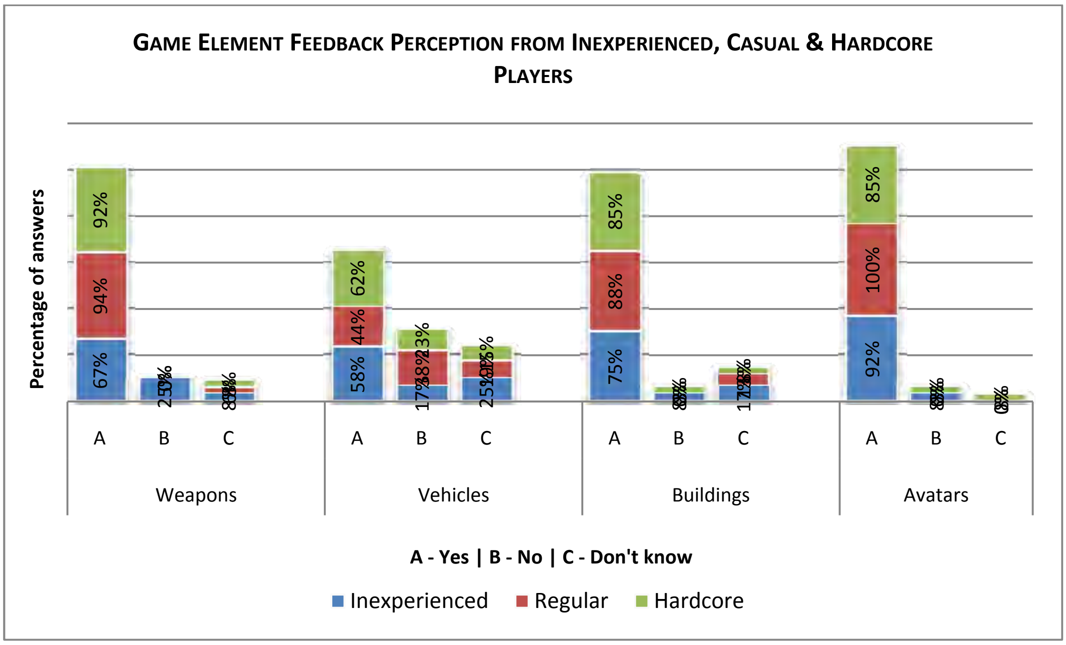
Moving on to **casual players**, in Question 3 E, the consensus – as the numbers indicate – was greater than what occurred with the inexperienced players. 88%, 94% and 100% indicated having perceived feedback from buildings, weapons and avatars respectively, when having interacted with them. However, when analyzing the answers for vehicles, 44% answered to having seen feedback and 38% said they perceived none. Therefore, this element was the most debatable among the players. Once again, similar to what occurred with the inexperienced players, only 6 of the answers were relative to the *don't know* option.

Considering Question 3 F, once again the participants agreed on the positive options: efficient and very efficient. 56% and 69% indicated that the feedback associated to weapons and buildings, respectively, was very efficient. On 4 occasions, 44% of the casual players coincided on their opinions: vehicles and avatars as being very efficient and weapons and avatars as being efficient. Among this group of participants, only two occurrences of *not knowing* were registered.

Finally, moving on to the **hardcore players** and, beginning with Question 3 E, the consensus among this group was less evident than what occurred with the inexperienced and casual players. 62% answered to having seen feedback from vehicles; 85% answered to having perceived feedback from both buildings and avatars and finally; 92% indicated having perceived feedback from weapons when interacting with this element. Similarly to what occurred with both inexperienced and casual players, the number of answers associated to the *not knowing* option were 5.

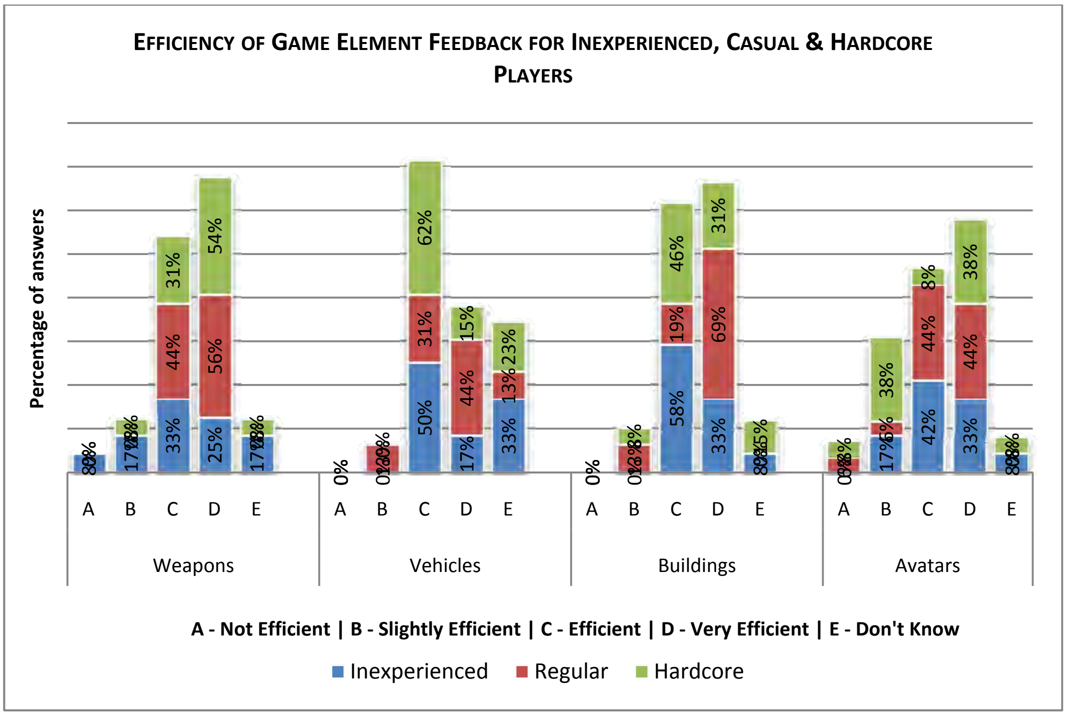
Moving on to Question 3 F, in the same way that occurred with inexperienced and casual players, only on two occasions did 50% or more of the participants agree, for the elements at hand, on their efficiency. 62% indicated that vehicle feedback was efficient whereas 54% answered that the feedback associated to weapons was very efficient. Under the 50% mark but still relevant were 3 results. 46% participants indicated that the buildings were efficient; 38% indicated that avatar feedback was very efficient while the same number indicated that the same element was only slightly efficient. Furthermore, only 7 occurrences of the option *not knowing* were counted.

Comparing the three categories of players' answers for Question 3 E, contrary to what occurred for the other questions, for each of the elements at hand - weapons, vehicles, buildings and avatars - there was a great consensus. This is to say that on 4 occasions (i.e. one per element), 50% or more of the players of each category indicated the same answer. Firstly, in what concerns the weapons element, 67%, 94% and 92% of inexperienced, casual and hardcore players, respectively, indicated that they did perceive feedback from that element. Secondly; 75% of inexperienced players, 88% of casual players and 85% of hardcore players answered that they perceived feedback from buildings. Thirdly, 92%, 100% and 85% of inexperienced, casual and hardcore players indicated having perceived feedback from avatars. It was on this element that the three player groups share a greater common opinion. Finally, for the vehicles element, only two groups shared a majority opinion: 58% and 62% of inexperienced and hardcore players, respectively, indicated to having perceived feedback from vehicles. These results can be seen in Graph 5.



Graph 5 - Game element feedback perception from Inexperienced, Casual and Hardcore Players (Question 3 E)

Moving on to the general analysis of Question 3 F; two occurrences of 50% or more of players from two groups sharing a similar opinion were registered. The first was related to the weapons element where 56% of casual players and 54% of hardcore players indicated that the weapons feedback was very efficient. The second was related to the vehicles where 50% of inexperienced players and 62% of hardcore players indicated that vehicle feedback was efficient. Nonetheless, despite some distribution of the answers, the general tendency of the players was to favour the positive answers - *efficient* and *very efficient*. Finally, a relevant result can be associated to the vehicles element where 33%, 13% and 23% of inexperienced, casual and hardcore players indicated that they could not classify the efficiency of this element. These results can be seen in Graph 6.



Graph 6 - Efficiency of game element feedback for Inexperienced, Casual and Hardcore Players (Question 3 F)

Looking now at question seven (Question 4 G) and eight (Question 4 H) their open-answer nature implies that a more qualitative analysis be made.

As seen previously in section 7.5.1, Question 4 G assessed the participants' opinions on various aspects of the two maps and modes they had played. The aspects covered were the luminosity of the maps, the number and diversity of buildings, the possibility the maps offered to explore, places to hide on the map and finally, the diversity of obstacles. Nevertheless, it must be noted that not all of the participants from the three categories offered input as this question was optional.

These questions and participants' answers will be explored aspect by aspect and then, as done before, in order of experience.

The first element brought to the attention of the participants was the luminosity of the maps. The great majority of the inexperienced participants offered no feedback indicating that they simply felt it was efficient. However, one of the participants expressed that the luminosity was efficient and in harmony with the war environment the game is based on. For that reason, the player felt it did not interfere with the gameplay. A second participant indicated that both interior and exterior luminosity created an interesting environment, crafting, therefore, a war-style atmosphere. The medium experienced players offered a slightly greater number of opinions. One of the participants affirmed that the exterior luminosity of both maps should have been greater for a superior experience. This idea contrasted with one opinion that the luminosity of the maps was excellent. Finally, one other participant said that the shadows made it difficult to properly view tri-dimensional objects. Moving on to experienced players, one of the participants indicated that the luminosity was very good and that it transmitted a true sense of war; two other participants, similarly to what occurred with one casual player, felt that the shadows complicated the gameplay and correct visualization of certain areas of the maps. Another participant mentioned the existence of good contrast when comparing interior and exterior luminosity as well as the positive lighting when explosions occurred. A final answer from one of the participants referred that the quality of the signal was not the best which made it more difficult to distinguish certain objects.

Moving on to the number of buildings present in the maps, inexperienced players, apart from affirming that they were efficient, stated that there were too many. These players felt that the maps were too dense in buildings and that either it was too much information to filter or too many spaces to explore. However, the idea that their inexperience contributed to these ideas was referred. The casual players that contributed with opinions had a similar view on the number of buildings: they felt that the number was excessive. However, one of the players referred that this could be seen as a positive or negative factor due to the fact that if on one hand there are many buildings, on the other hand, this creates a greater number of places to hide when playing. Finally, experienced players indicated that, similarly to inexperienced and casual players, that there were a large number of buildings. However, many of those who answered preferred a positive view indicating that a larger number of buildings also created a larger number of spaces to explore and various paths to a same place on the map.

The third aspect was the diversity of buildings. Inexperienced players indicated that the diversity was in general efficient. However, four of the participants indicated not having noticed a great diversity in the buildings that compose the maps. Casual players indicated not having noticed sufficient diversity in the buildings. Two of these, however, said that there was a positive diversity. Finally, hardcore gamers were divided in terms of their opinions: some felt there should have been more diversity and others felt that there was a vast diversity of buildings, creating an environment similar to what can be seen in the real world.

Moving on to the fourth aspect in discussion, the possibility of exploring the maps, only two inexperienced players projected an opinion. One of these participants indicated that the maps offered great possibilities of exploration while the other participant felt that it was in some way limited, especially inside the buildings. Casual experienced players offered a greater number of opinions. Some felt that the maps had many places and content to explore; others felt that, taking into account some limitations in building diversity, that the places to explore were limited. Some of the other casual players indicated that the maps weren't sufficiently interactive (doors couldn't be open). Finally, hardcore players tended to share the same ideas: that the maps offered many places to explore, many paths to a same location and that buildings could also be explored. However, two of the hardcore participants did indicate that the possibility of exploring was not sufficient.

Taking a look at the fifth element that was analysed by the participants; only one of the inexperienced players offered an opinion in what concerns the number of places a player could hide. This participant indicated that the maps offered many places to hide such as cars and buildings. Casual players' answers were more diverse: some indicated that the number of places to hide was large; others mentioned that in fact there were many places to hide but simultaneously not all were completely safe, which in turn prevented players from constantly "camping"[23]. Finally, many of the hardcore players that shared an opinion indicated that there were various places on the maps – windows, balconies, stairs and behind cars – which were good to surprise and fire upon enemies. Also, they felt that this factor contributed to a more realistic representation of a war-zone. Only one of the hardcore players that answered indicated that amount of places to hide was reduced.

Moving on to the final aspect of the game, the diversity of obstacles present on the map; no more than two inexperienced players shared their opinion. One of those players indicated that there weren't enough obstacles, especially *natural* obstacles such as explosions. The other player indicated that there were too many obstacles and that these at times made it difficult for them to find their enemies. Casual experienced players contributed with the general idea that there was in fact a large diversity of obstacles that represented what could traditionally be found in places of war. Furthermore, others considered that despite their being a good quantity of obstacles, many of these were static and offered no functionality such as car doors opening. In addition, one of the casual players indicated that there were too many obstacles in the two maps which in turn made the environment a bit confusing when first entering the game. Finally, there was some divergence of opinions among hardcore players. Some of these players felt that there was a good number of obstacles that simultaneously complicated and made the gaming experience more exciting and realistic; another player felt that there were too many obstacles filling the map and especially the streets; lastly, some players simply indicated that there was a vast diversity of obstacles whereas a final participant felt that there was just too many obstacles on both maps.

The final question participants were asked to discuss was once again of open-nature and therefore not all participants contributed. However, some topics were brought up in the answers collected.

Analyzing inexperienced players' contributions, there were more negative ideas than positive. Some of the collected answers were directly related to the hardware and technological limitations inherent to the study. The players found that the delay between their mouse movement and the actual result of that movement in the game complicated their participation at times. Consequently these players found it harder to control the player as well as firing the weapon. Another participant, similarly to what occurred in the previous question, found that there were too many buildings which made the environment more confusing and made it difficult to choose where to go. Another participant felt that the number of visual stimuli complicated their tasks having also mentioned that the game in general made it difficult for inexperienced players to successfully complete tasks. Nonetheless, some of the inexperienced players did mention that they thought that both the game and the experience were fun and that the experience transmitted a true sense of "war".

Moving on to medium experienced players, similarly to what was verified with the inexperienced participants, there was more negative feedback than positive. One of the players felt that the beginning of the game was confusing and not clear in terms of objectives; another indicated that both maps were confusing and finally, a third player indicated that despite the game being very realistic, at times it was difficult to find allies or enemies on the maps. In terms of positive input, the realism of the game was once again mentioned as well as the gameplay.

Finally, a look at hardcore players' opinions shows a more equivalent spread of feedback. One of the hardcore players felt that the enemies' artificial intelligence was excessive; a second player referred to the

[23] Camping is the act of a player remaining in one area of the game map waiting for their opponents to appear or come to the player rather than actively looking for them; this technique is used in games as a method of gaining advantage over other opponents.

game menus, indicating that they were not always clear for the players. Also mentioned by the same player were the apparent non-existing reactions and collisions between the player and the generated bots. Moving on to the positive aspects of the game, the general tendency was to indicate the game as being very realistic and the gameplay as also being good. Other players indicated that graphically the game was one of the best they had played and a final player simply indicated that the game was "5 stars".

Another part of this question was related to participant suggestions for the game. This will be looked at in the following section of this dissertation when the questionnaire results are analysed.

8.2. Eye tracking data processing and integration

The methodology previously presented in section 7.5.2 and used to build the heat map representing the hardcore players' in-game movements provided a variety of interesting results as can be seen in Figure 28 and Figure 29[24].

Quickly recapitulating the steps that led to the building of these heat maps; a grid was created and placed over an illustrated representation of the *Strike* map the participants played on. The following step required that for every sample made on Tobii Studio software timeline (associated to the participant's recording), an extensive look at what was in their range of view be analysed and furthermore, be represented on the map. Therefore, for all the areas visible to the player for a particular sample, all the corresponding quadrates of the grid would be coloured. This process would then be repeated for all twelve of the participants bearing in mind that if a certain area had been already seen, it would be coloured with the next colour of the palette.

Figure 28 demonstrates the first four participants' representations. As can be seen, there are many areas of the map that were only visualized once (dark blue – first colour of palette) as well as others that were seen by all of the first four participants. Additionally, and as can be seen, after the first four participants' representations, many of the areas on the map remained unseen by the participants.

The opening – place where one of the teams begins the game – as well as the corridor that leads to the central area of the map, represented by area 1 and area 2, respectively, were areas that contained quadrates that all four participants saw. The same can be said for the main corridor of the map (area 3) and the open area in 4. Contrary to what occurred in area 5 – location of one of the flags – where up to 4 of the participants looked, other places on the map where flags could be found (area 6 and to the left of 2) had at most received two of the participant's views. Area 7 was visualized by a single player while area 8 had received no interest.

[24] For complete selection of all the maps representing the evolution of the peripheral view heat map please consult Appendix 4 – Heat map development.

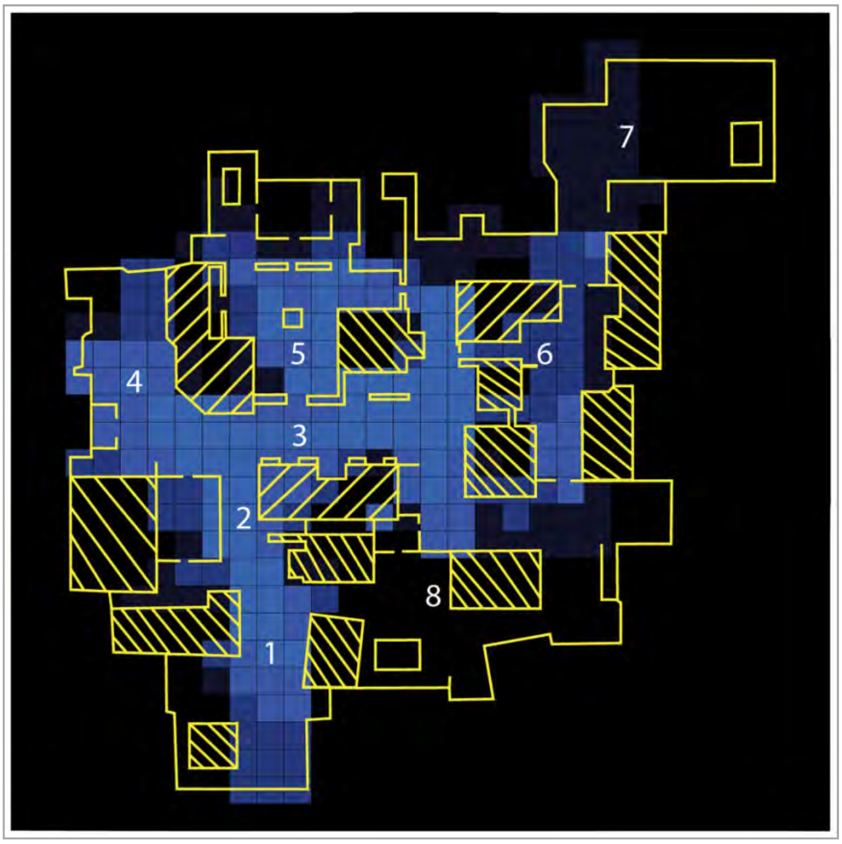


Figure 28 - Heat map representing hardcore players' views (4 participants) and important zones of analysis

Now considering Figure 29 which reflects 8 participants’ representations; areas that were and were not seen by any of the players are more identifiable. Area 1 continued to capture much of the players’ attention as did area 3, with all 8 participants having passed their eyes on that part of the map. The area identified by 2 – location of one of the flags – had now been seen by at least 5 of the participants. The area represented by 4 continued to be seen by a good portion of the players while area 5 witnessed a slight increase as well. The main corridor of the game – the street that runs through the centre of the map – represented by 6, continued to attract all of the players’ attention. Close to that value was another region where one of the flags is placed, area 7, with some of the quadrates having been seen by 7 participants and other spaces seen by slightly less. However, area 8, just above, had little or no attention from the first 8 players. Another street on the map – area 9 – also attracted some of the participants’ attention; although more to the right then to the left. Area 10 continued to be “problematic” bearing in mind that, at most, 4 of the participants looked at that area. Area 11, localization of a third flag, contains quadrates that received up to 7 of the participants’ views, revealing itself as another important area of the map. Area 12, which up to the first 4 participants had a minor significance, received some views from the next four participants that played. Finally, area 13 continued to be a dead zone in terms of player visits and interest.

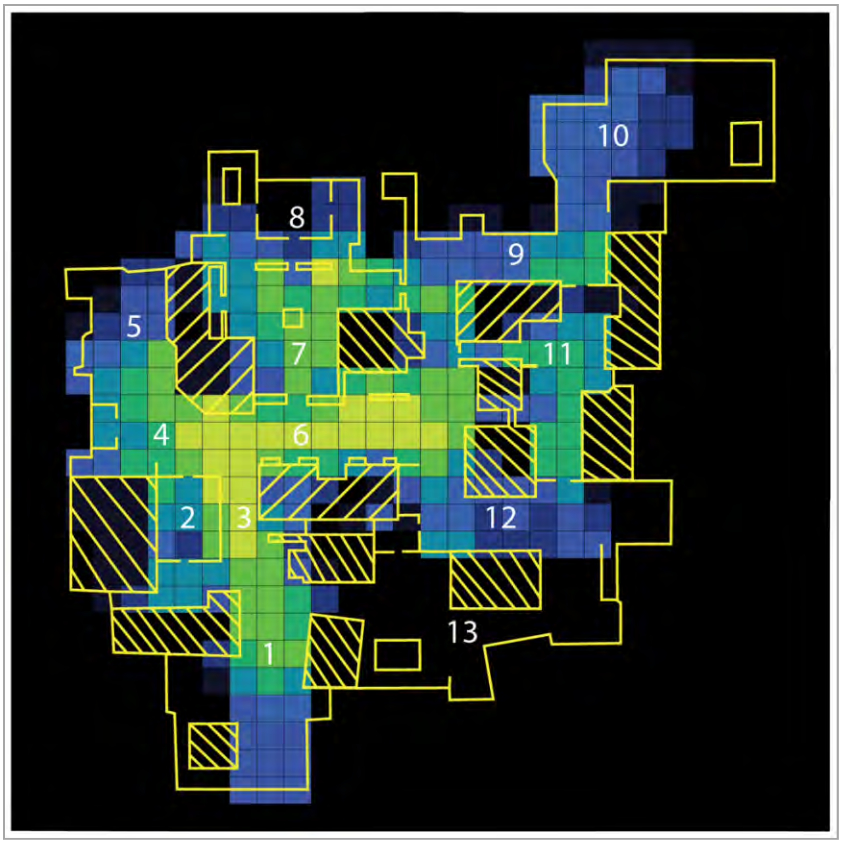


Figure 29 - Heat map representing hardcore players' views (8 participants) and important zones of analysis

The final heat map of interest can be seen in Figure 30[25] and is the result of all twelve hardcore players' visualization representations. As expected, the diversity in player movements and options throughout the tasks resulted in the players visually exploring different areas of the map. This aspect resulted in various areas of different "significance" which in turn can be seen by the 18 points marked out in Figure 30.

Area 1 and area 3 now have their separate regions due to the fact that area 3 was one of the most visited areas of the map with 10 participants having seen that precise region; on the other hand, area 1 had only 6 (half of the participants). Area 2 is referred to for the first time as it was part of the grid that was seen by up to 3 participants. One of the areas that held a flag – area 4 – and contrary to what was expected only received 7 views from the hardcore players. However, and as occurred with the first two presented heat maps, area 5 was one of the most active regions having been seen by 11 participants. Areas 6 and 7 of the grid represent two regions in the same corridor that had a distinct number of visits: area 6 had up to 10 player visits while area 7 had less impact having only seen up to 5 players' visualizations. Area 8 is another region mentioned for the first time. The quadrates in this area belong to the interior of a building but, nevertheless, received up to 3 views from the participants. The map's central corridor, as seen in 9, represents the most active area of the map having been seen by all twelve participants. To the left, right and even above the indicator are quadrates of that region that received either 11 or all of the players' views. Area 10 represents a second location where a flag was placed and contrary to what occurred with

[25] For a larger and more detailed view of Figure 30 consult Appendix 5 – Peripheral vision and point of regard heat maps.

area 4, this part of the grid concentrated a greater interest from the players having received up to 10 views. Area 11, just above 10 and near the map border, did not receive significant interest from part of the players; only one of the quadrates in the region received 5 views whereas the remaining quadrates had 4 views or less. The corridor represented by 12 had a significant number of views from the participants: from 5 to 7. A different corridor, 13, had a diverse number of visits but, nevertheless, always a significant number including a maximum of 10 in one quadrate. Area 14, in the top-right was one of the poorest areas in terms of significance having only received, at most, 5 views from the participants. Moving downwards, area 15 represents the final region where a flag was placed and once again, this area received a significant number of views – 8 and 9. Areas 16 and 17 represent two distinct regions of interest. Area 16 had a less number of views (from 4 to 6) whereas area 17 received either 7 or 8 views from the participants. Finally, area 18 witnessed a trend that lasted nearly the entire analysis. Of all the hardcore participants, only on one occasion did one of those participants look at the region represented by 18, making this region the poorest in terms of significance.

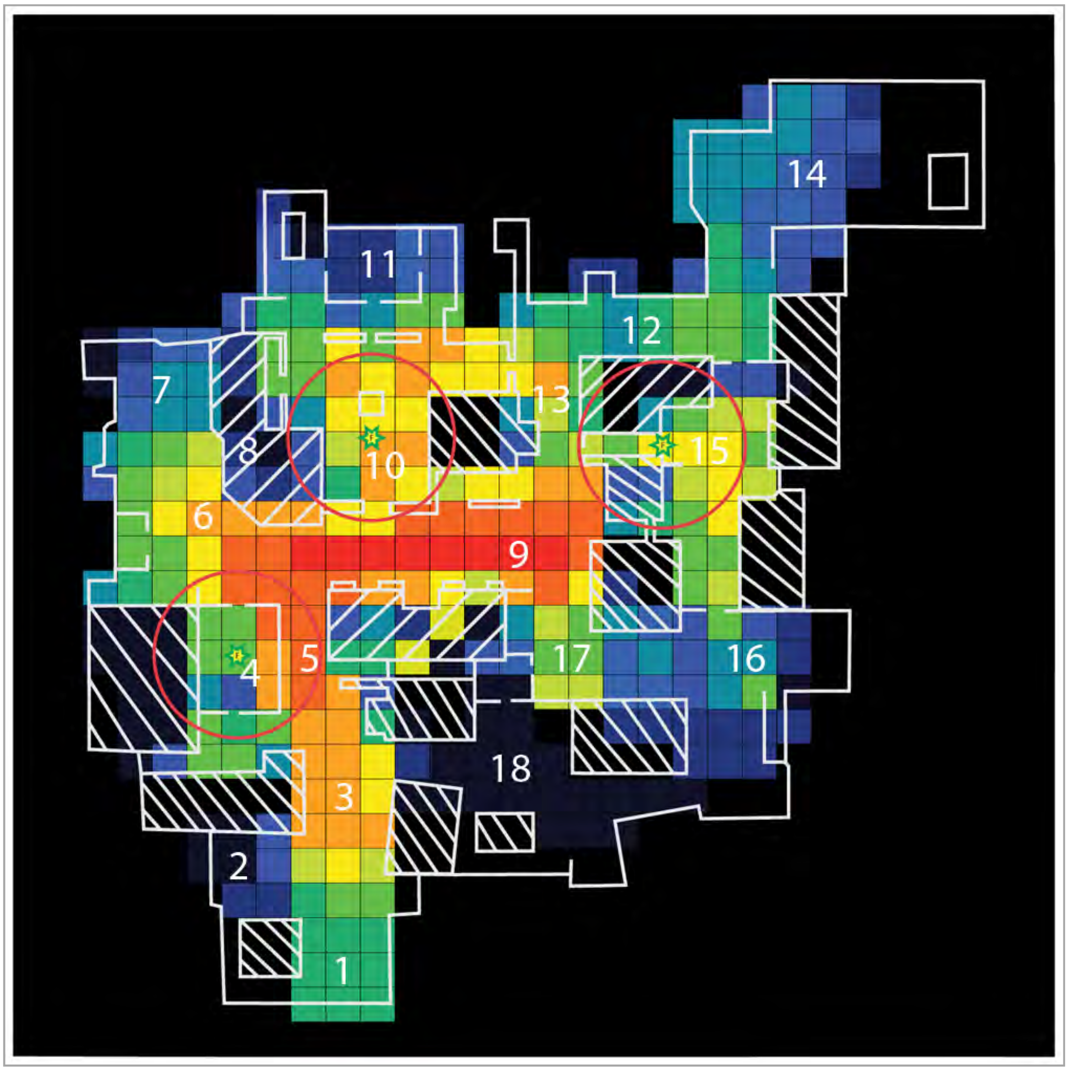
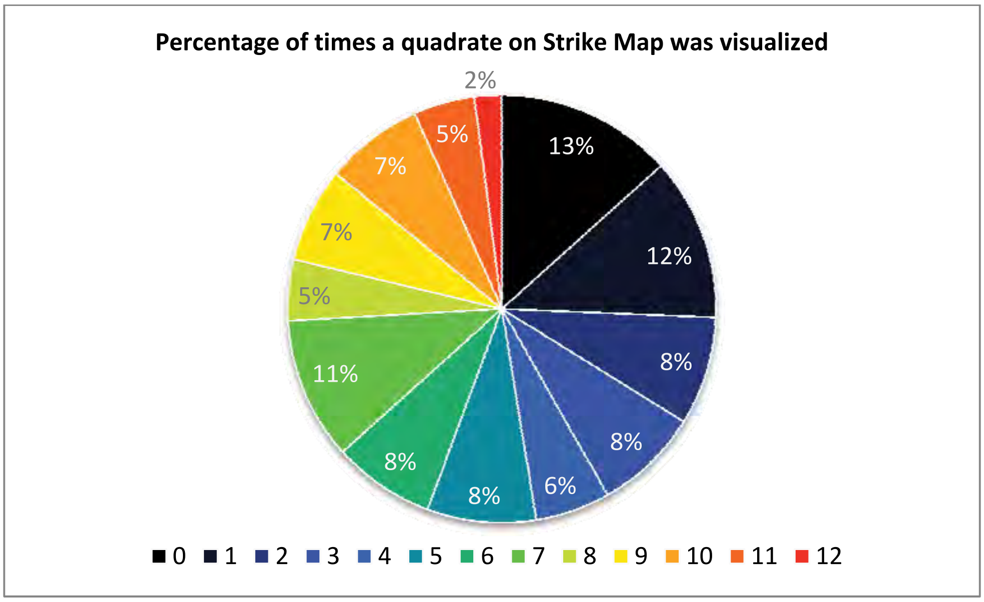


Figure 30 - Heat map representing hardcore players' views (12 participants) and important zones of analysis

A broader look at the heat map suggests 5 regions of concern: area 7, 11, 14, 16 and 18 with the number of maximum views in the quadrates of each of these areas being 5, 4, 5, 5 and 1, respectively. That is, 3 of these regions caught just over 40% of the players' attention; one of the regions a third of the players' attention and finally, one of regions claimed a single player's attention.



Graph 7 - Representation of the distribution (in percentage) of the number of quadrates viewed by the participants

Number of visualizations	1	2	3	4	5	6	7	8	9	10	11	12	Not seen
Number of quadrants	48	32	31	22	32	30	42	18	28	29	18	8	52

Table 3 - Total number of quadrates that received from 1 to 12 participant general visualizations

Finally, looking at the general picture, and as can be accompanied with the data present on Graph 7 and Table 3, the total number of quadrates that were associated to the Strike map were 390. In other words, there were 390 different quadrates that could be codified according to the participants' visualizations. Table 3 indicates the total number of quadrates that received – in ascending order – up to twelve views, and therefore, all of the participants' observations. That is, exemplifying, 48 quadrates were seen by only one player, 32 quadrates by 2 participants, 31 by 3 players and so forth. Furthermore, Graph 7 presents the share (in percentage) of that same distribution, using however, the same colour scale applied to the heat maps.

Graph 7 shows that there was some congruity among the percentages obtained and that no value claims a greater importance. However, the graph also shows that, despite all twelve participants having seen the area represented by 9 in Figure 30, this small division only represents 2% of the total visible map. In addition, the graph also specifies that 13% of the map was not seen by a single player.

If up to this point one could argue against the validity of the methodology, claiming that in fact the true power of the eye tracker had not yet been seen and that these heat maps could have been built using any video recording; the following heat map represents the participants' views on a different level. While in the previous heat map the exact location on the screen the players were looking at was disregarded and therefore, everything in the players' range of sight for the selected samples was considered, the following heat map is the opposite. In fact, the eye tracker does indicate the precise location on the screen where a player is looking – as can be seen in Figure 22 and Figure 23 – and that location can be translated into a point on the illustrated map.

Therefore, and using the same approach as done with the general view heat map, for each of the players and for every sample marked on the timeline, the quadrate on the grid that corresponded to the area or element on the map the player was looking at was codified. This *point of regard* heat map can be seen in Figure 31.

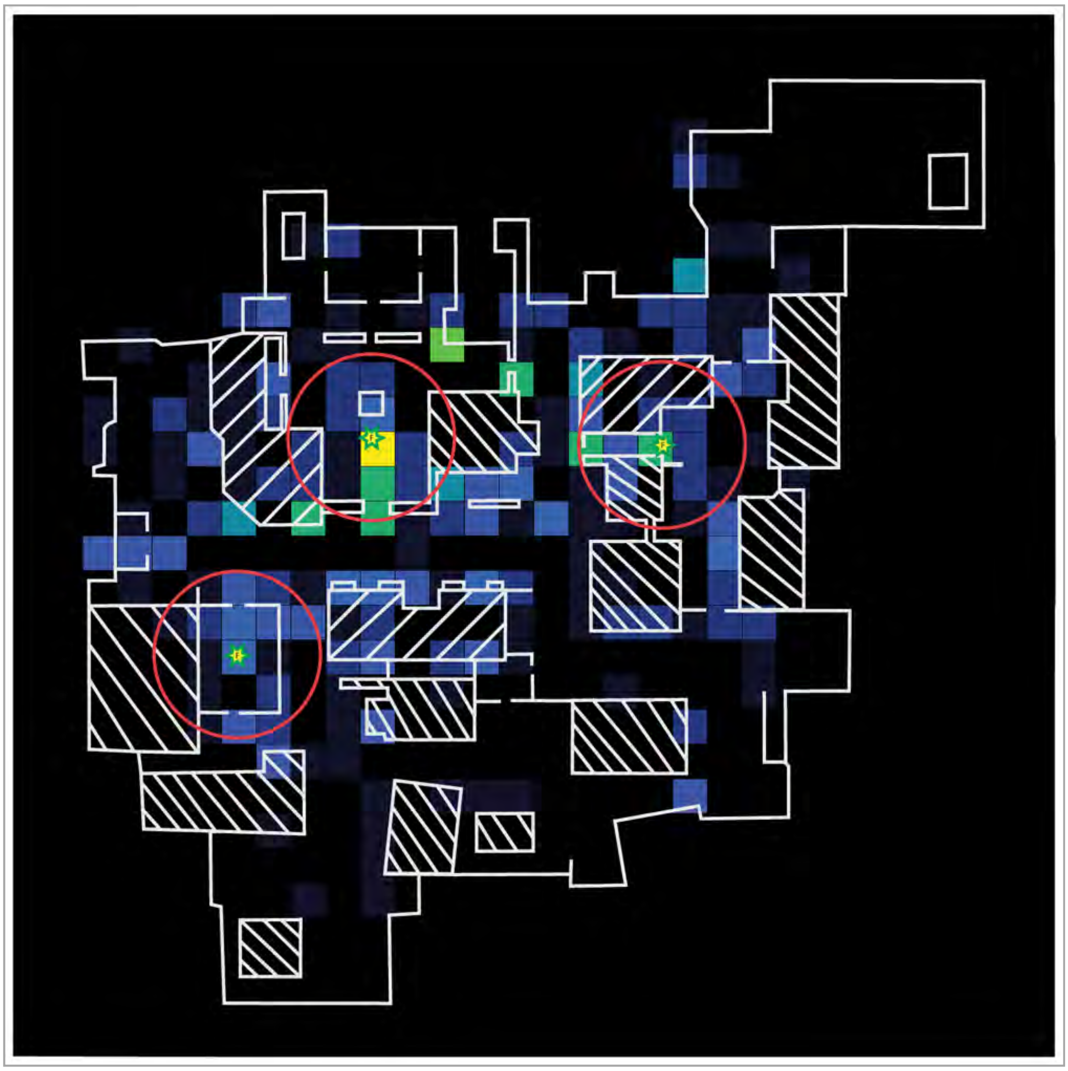
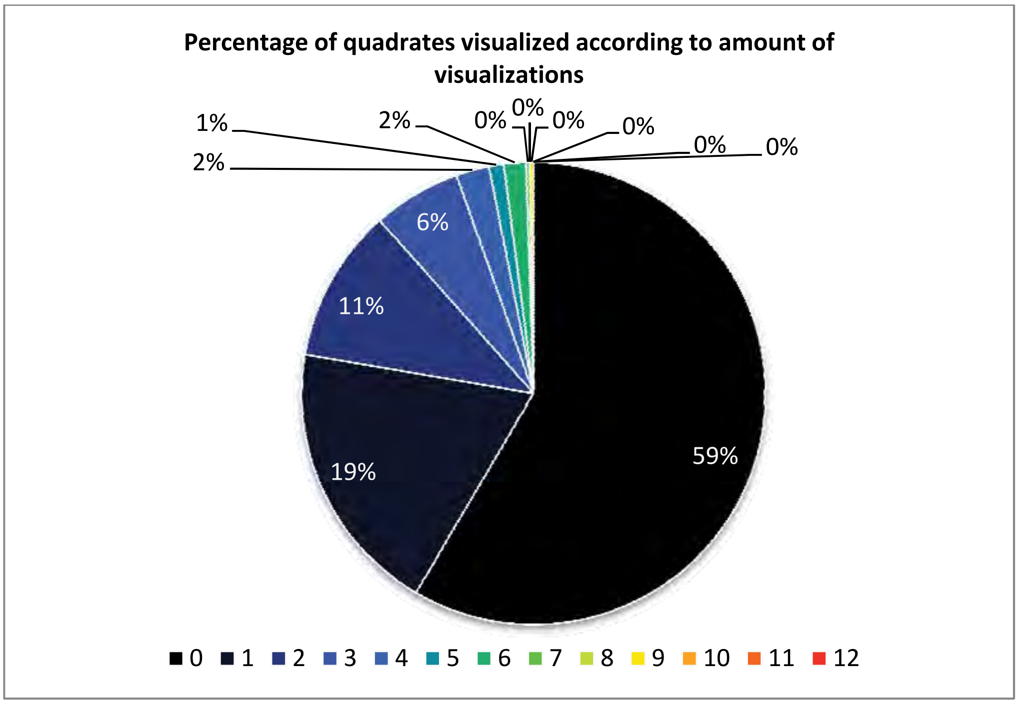


Figure 31 - Heat map representing hardcore players' point of regard according to sampling frequency

The first point of analysis that surfaces as a result of the heat map is the emptiness in colouring. While in the general heat map colour intensity was very present, the lack of colour in this map is also evident. To understand the heat map at hand, it must be clear that only one quadrate was codified for every sample taken. That is, and to exemplify, if samples were taken at second 10, 15, 20 and so forth, for player x, then the only quadrates coloured would be the those that correspond to the area or element in the game the player was looking at (e.g. a door, a window, an enemy, a car, among others) at those precise seconds.



Graph 8 - Representation of the distribution (in percentage) of the quadrates viewed by the participants

Number of visualizations	1	2	3	4	5	6	7	8	9	10	11	12	Not seen
Number of quadrants	75	42	24	9	4	6	1	0	1	0	0	0	228

Table 4 - Total number of quadrates that received from 1 to 12 participant detailed visualizations

That said, and analyzing this second heat map, it's clear that there are some areas of interest, many areas of minor impact and even areas with no significance at all, having not received a single view. As can be seen, the regions that received greater attention from the participants were those closest to the flags; areas where the players spent a greater part of their time completing their objectives. Also, to understand the differences between both the general heat map and a *point of regard* heat map, if in the first, the street that crossed the centre of the map was the most "active" area, in this second heat map, that same street is dramatically insignificant.

In terms of numbers, as seen in Graph 8 and Table 4, of the 390 quadrates that compose the visible and explorable map, 228 of those were not seen once. This value corresponds to just under than 60% of the map. Also, 19% of the map – or 75 quadrates – represents areas only seen once. Furthermore, just over 10% of the map represents quadrates that were seen by 2 participants. From here on, the numbers are very insignificant. Finally, the quadrate that was seen by the most number of participants – 9 – only accounts for one of the 390 quadrates and represents the quadrate where the central flag is located.

Having presented the results obtained via both the questionnaires as well as the eye tracker, the next part of the study will focus on discussing some the acquired results.

8.3. Results analysis and discussion

We've seen the various results generated by all 41 participants' input on the questionnaires; we've also seen how the analysis of the hardcore players' movements during one of the tasks resulted in two heat maps with valuable information. However, and as occurs with all studies, the achieved results must be analysed, discussed and challenged.

8.3.1. Questionnaire Analysis

One of the main reasons behind the use of three distinct categories of participants was to show that in fact, different gaming experiences results in different game approaches as well as distinct manners of visualizing a game (Bavelier & Green, 2003) & (Castel, Pratt, & Drummond, 2005). As the questionnaires were the only instrument used to gather all of the participants' input, the results acquired via this instrument will be the first to be analysed. Furthermore, for a more thorough look at the eventual differences, the order in which the results were presented will once again be used here.

In Question 1 A; only on 3 occasions did the majority of inexperienced players agree on the same level of influence for the 7 elements presented. As a result, many of the answers were fairly distributed among the various options. However, of the three mentioned occurrences, only one was relative to the agreement that the elements do influence eye movement. That element was precisely buildings. This suggests that in fact while playing, inexperienced players may spot out graphic elements of greater dimension, such as buildings, but other important details, are of less significance. Casual players' answers resulted in 4 occurrences of a 50% or more agreement. Contrary to the inexperienced players, this tendency was verified on the positive side of the table – *influences* and *influences greatly*. Hardcore gamers, on the other hand, registered 5 occurrences of a minimum 50% agreement, all of which admitted that the element influenced or influenced greatly their eye gaze. This suggests, and as occurred with casual players, that hardcore players pay attention to big detail (e.g. buildings) but also to other graphic elements that influence a game such as the stairs and windows; places where an enemy could be hiding, waiting to shoot upon other players. In addition to the mentioned, contrary to what could be expected, only casual players answered with some agreement that balconies played an important role in where they looked. The fact that all the other elements listed were chosen as important by the hardcore players suggested that, contrary to what occurred, balconies be also mentioned, as they, similarly to windows, serve as a place where enemies can hide. Despite this, the consensus that most of the elements do influence the hardcore players gaze indicates that there is a constant concern to locate places where the players can hide as well as places where their enemies could be camping; an idea that is not completely clear with the other players. Along with stairs and windows, also walls and cars play an important role in where the hardcore players look; an idea that does not find equivalence with inexperienced players. Trees, an element that no category of players felt that influenced their eye movement was, and as will be seen later on when analyzing the heat maps, one of the elements in focus.

Moving on to Question 1 B, the results indicate that inexperienced players were in agreement more than in the previous question (Question 1 A). However, the verified tendency was to agree on the negative side of the board; that is, to answer that elements do not influence or only influence slightly. This result demonstrates that their choices in movement are not the result of an analysis of their surroundings, the elements that can assist in their games strategy as well as the consideration of the best choice in direction. This idea improves, nevertheless, when analyzing casual players' answers. There were 6 answers that received 50% or more of the players' agreement; 3 on the positive side and 3 on the negative side. Casual players indicated that buildings (also mentioned by inexperienced players), stairs and walls do influence their choices in movement which suggests that their choices in movement are not completely random. Furthermore, the indication that stairs do influence their character movement, contrary to balconies or windows could suggest a greater interest in additional forms to enter a building so that they may be explored. Contrary to the other categories of players, hardcore players agreed less on the elements that influenced their choices in movement. However, the answers on which they agreed were either to say that the elements do influence or influence greatly. Two elements not mentioned by the hardcore players as elements of the game environment that condition their movements were the walls and the cars. This contrasts with what was seen in Question 1 A when the hardcore gamers indicated that they do condition their eye movement. Therefore, it is plausible to think that hardcore players believe that these elements serve as protection for enemies and for that reason; they look at these elements to search for them. However, when the option is using those elements for their own protection, it appears that this solution is not consensual. Finally, it must be referred that for the three groups of players, 50% or more of the participants in each group indicated that buildings influenced greatly their choices in movement. This was the only element in which they all agreed unanimously which can be seen as a natural response. In any game, exploring is a common behaviour and in fact, the buildings in the maps that were played were explorable.

In Question 2 C, the general tendency among inexperienced players was to agree that the presented interface elements were in fact efficient. This agreement occurred on 6 occasions, one of which resulted in over 80% of the players' agreement (utilities element). Casual players however, did not show the same level of union as inexperienced players. Rather, their answers were distributed among the scale options. Finally, on 4 occasions, 50% or more of the hardcore players agreed that the listed elements were efficient. The question that surfaces, bearing in mind the presented results is to what extent the inexperienced players really believe the iconography used is efficient. In fact, while answering the questionnaires, many of the inexperienced participants indicated that they hadn't noticed most of the elements on the screen and were only able to answer the questions using images. In addition, for many of the participants, it was necessary to indicate what each of the element was and what it represented. Furthermore, 83.3% indicated that the utilities icon was adequate; utilities that in turn were never used by a single inexperienced player. These facts can certainly question the validity and logic of some of these answers. Nonetheless, if the elements were analysed purely in terms of their aesthetics without considering functionality, these answers could have a more valid reasoning. The consensus verified on 4 occasions with hardcore players can be seen through two perspectives. (1) One perspective could be of similar nature as that justified the inexperienced players' results; that is, the hardcore players analysed the icons in terms of their aesthetics. (2) The second perspective is that, having experience with video games of the same genre and therefore contact with similar iconography, these players quickly and easily identified the interface elements, understanding their significance and evaluating not only aesthetics but also functionality. If so, in evaluating the elements' functionality, questions such as the following would have been asked: *do I know how much time I have left?*; *do I know how many points I have and what team is mine?*; *how many grenades and what ammunition do I have left?*; *does the map represent where I am in the game environment?*. Finally, it must be said that the map was the interface element that best *score* received having an overall (all the participants) acceptance of 92.7% (efficient & very efficient). The map is an interface element traditionally found on First-person shooters and other game genres and therefore is possibly the most recognizable of the elements listed.

Moving on to Question 2 D, once again, the general tendency of all the participants was to indicate that the presented interface elements were either efficient or very efficient. This occurred for all three categories of players. In what concerns the inexperienced players, on three occasions one of the elements received a minimum 75% of the answers which brings up once again the same questions analysed in Question 2 C. However, bearing in mind that in Question 2 D players were asked to analyse the localization of the element and not so much its functionality, the answers could be the result of an opinion of what they thought was or was not correct in terms of interface placement. Casual players' answers also showed a good quantity of agreement which, bearing in mind the lack of comments offered by these players, could also be the result of their opinion at the time of filling out the questionnaire. Finally, hardcore players' answers demonstrated some agreement but also some differences of opinion. Although on three occasions three interface elements received more than 50% of the participants' answers, there were also various occurrences of the same elements receiving respectable percentages of disapproving opinions – *not efficient* & *slightly efficient*. This occurrence could indicate some disapproval towards the localization of these elements; possibly due to the fact that some of the players are more accustomed to the localization some of these elements assume in other games of similar nature.

Now analyzing Question 3 E, the validity of the answers received doesn't offer much questioning as the answers are of simple nature. In fact, and analyzing the combined results of all the players; percentages of 85%, 54%, 83% and 93% for the weapons, vehicles, buildings and avatars elements, respectively, indicates that in fact the feedback in Call of Duty 4 is visible when players interact with those elements. Approximately 27% of all the players indicated that they did not see feedback from the cars which could possibly be the result of three ideas: (1) the conditions in which the game was played made it difficult to spot the feedback generated by the game (slight smoke and sparks) or, (2) when having fired upon the vehicles, the distance at which it was done was such that it was difficult to have spot the feedback. (3) A third possible explanation could be related to what the participants expected the feedback to be (e.g. cars randomly exploding, doors being able to open, or others) and having not seen this feedback, indicated such in their answer. However, this possibility was predicted and therefore, when responding, the type of feedback associated to the car was explained.

Moving on to Question 3 F, and as the results of Graph 6 demonstrates, the majority of all the players indicated, for the 4 elements at hand, that these were efficient and very efficient. Nevertheless, 20% of all the players (inexperienced, casual and hardcore players) indicated that avatar feedback was only slightly efficient, a significant result. As some of these players pointed out while responding to the questionnaire, although they understood that the enemy was being hit by the ammunition, the lack of animation from the avatars until they fell on the ground dead was one of their concerns. However, to justify this in-game problem, it must be once again said that the players played against *bots* with artificial intelligence, programmed by an exterior person to the game. The bots assume the body and resemble enemies that one might find when playing the game in single-player mode or even in the original multiplayer mode but their behaviour is slightly different. Hence, the original game itself is not responsible for the lack of animation in these enemy players in particular.

Question 4 G requires a distinct type of analysis as the answers that were received were of an open-answer nature and not all participants gave their opinion. However, it is still necessary to look at what could be behind some of the negative answers offered by the participants.

The first aspect analysed, the luminosity of the maps, revealed a minor diversity in answers. Those who positively commented on the luminosity indicated that both interior and exterior illumination of the maps was efficient and that it helped set the "war" atmosphere. However, other player's also indicated that the luminosity was confusing and that it made the gameplay more difficult. This can be a direct result, as one of the players mentioned, of the quality of the signal. In fact, it must be reminded that the video game that ran on the eye tracker's monitor screen was a video signal that was being sent from the host computer running the video game. The host computer running the game sent the analogic video game signal to the movie box which in turn re-sent it via a digital signal to the Tobii monitor. The codecs used to compress the video signal – so that the signal being received was smaller (in data size) – also played a part in the slightly worse quality of the detail of the game. These elements all played a role in the difference in the quality of the graphics which in turn was visible to some of the more acute players.

The second aspect, the number of buildings, resulted in many players of all categories indicating that the number of buildings was excessive. Although the participants' opinions are definitely valid and welcome, one of the factors that lead to the choosing of the used maps was in fact some density in buildings so that there were more places to explore and less open spots. However, it must be referred that these two maps are only a small portion of the various and diverse maps that Call of Duty 4 offers to its players.

As for the third aspect, the diversity of buildings, once again, and as occurred with the number of buildings; many participants indicated that they felt the variety of buildings was minor. A greater portion of these, however, were the inexperienced players. Bearing in mind that the inexperienced players' answers relative to what elements of the game influenced their eye movement resulted in no obvious consensus, it can be hypothesized that the details of the buildings that in fact play a part in their diversity were not entirely noticed. Nonetheless, some hardcore players did indicate that there was a good variety of buildings, an opinion that corroborates the choices in the maps used. In fact, it is believed that the maps chosen, especially the *Strike* map used for the *Domination* mode is a map with a good diversity of buildings and structures. In addition, it must be accepted that the maps chosen were those that felt offered the best conditions for the objectives to be completed.

The fourth aspect is the possibility of exploring the maps. Once again, the answers spread to two main ideas: the first, that the maps offer a great possibility of exploring; the second, the possibility of exploring is limited. In fact, it is believed that both opinions are correct. Both maps do offer a good quantity of area to be explored; many open streets and many paths to a same place. Nevertheless, the possibility of exploring the buildings is in some manner limited; some buildings are completely open while others are completely closed. Furthermore, even those that are open are in some way limited as they have doors that can't be opened, an aspect mentioned by one of the players. Even so, it is still believed that the chosen maps did offer sufficient diversity of explorable area.

The fifth element, the quantity of places in which a player could hide, resulted in the majority of the players indicating that in fact the map is rich in this type of aspect. Nevertheless, some other players contradicted this belief. The greater share of answers came from the hardcore players that indicated that in fact the map offered various places such as windows, balconies, walls and cars, elements that could be used as shelter to hide from enemies as well as places for enemies to wait and camp. The received answers – and as will also be seen in the following and last aspect to be considered – can be seen at the light of *player tactics*. Players that value a strategic approach to a video game will more likely welcome a map with various places to hide instead of a map with open spaces and less places to hide where shooting is easier done at a distance. Also, as said for the other aspects, it is believed that the maps chosen offered the correct quantity of places to hide.

Finally, the sixth aspect, the diversity of obstacles; one of the inexperienced players indicated that he felt there should have existed more natural obstacle such as explosions – an interesting suggestion. In addition, some of the casual players indicated that despite encountering a considerable amount of obstacles, many of them were static and presented no interactivity (e.g. car doors opening). However, despite this lack of interactivity, some players did say that the existing diversity of elements contributed to the creation of a war-zone. As explained in the previous aspect, the diversity of opinions can be justified considering each one of the players' game strategy. Those who appreciate a more tactical approach to the game will present a greater interest in obstacles as they serve as shields from gunfire as well as places to hide. However, players with a minor interest in tactics will possibly feel that those elements are, as their name suggests, mere obstacles complicating the completion of tasks.

Now looking at Question 4 H and the participants' general feedback in terms of their experiences, as seen, both positive and negative feedback was acquired. The delay mentioned by one of the inexperienced participants was a factor that was present for all of the participants and, above all, inevitable. The adopted technological setup for the case study was believed to be the most reliable answer for the needs of the study and furthermore, a superior technological performance would have been very difficult to achieve. Therefore, and predicting difficulties from players of all categories, the empirical study was built on two tasks of distinct nature and objectives, so that when the task of greater importance was carried out, the players would be more at ease. One of the dilemmas pointed out by a player was relative to the level of artificial intelligence of the bots. This player indicated that they felt the AI level was exaggerated and that the bots were always killing the participant's avatar. Although this participant's question is valid, the level of artificial intelligence remained unaltered throughout the entire study and for all the other participants. For that reason, this possible problem cannot serve as justification for any problems encountered throughout the tasks. On a final note, many of the participants did feel that the game was in fact as good as some of the critics say.

Before moving on to the analysis of the heat maps, as mentioned earlier, part of Question 4 H asked the players to offer suggestions for the game. This question resulted in some interesting ideas from players of all gaming experiences.

One inexperienced player indicated that enemies and peers should be more easily identifiable in the Domination mode. When in combat, distinguishing enemies from *friends* is not an easy task and therefore, more distinct clothes or a different type of symbol on top of the players' heads could be used to assist in the identification. A second inexperienced player felt that the game should offer more possibilities of vertical exploration; that is, exploring the buildings up to their roof. Also, the same player indicated that the game could benefit in terms of sound if, for example, shots being fired from the right were only heard on the right channel and vice-versa, creating, therefore, a more rich experience and taking full advantage of the audio aspect of the video game.

Moving on to casual players; one of the participants indicated that the game lacked some interactivity with the other bots of the same team. This player indicated that the Domination mode could benefit if the possibility of strategic planning was possible; that is, one player would assume the command and tell the other bots where to go and what to do. Another participant indicated that he felt some difficulty in understanding the origin of some gunfire and that the game could benefit if some type of signal with this indication appeared on the interface. A third casual player said that cross-hair on the centre of the screen should remain static throughout the game so that when aiming and firing the weapon, the gun shots were more precise.

Finally, one of the suggestions received from a hardcore player indicated that the game map should be accessible at any time through the use of key. Also mentioned by the player was the cross-hair issue; a topic previously mentioned by one of the casual players. A second suggestion was related to the number of weapons at the players' disposal. In fact, in this mode, the number of weapons is somewhat limited. However, other modes allow the use of a greater number of weapons and therefore, the limitations of one mode are not always repeated in others. A final suggestion from a hardcore player, and as mentioned by one inexperienced participant, is that the game should have a more tactical option where bots could be commanded and where information about the bots' status and what they see could be viewed.

These suggestions terminate the analysis of the questionnaires. However, and just as important, is the analysis of the information presented by the heat maps.

8.3.2. Eye Tracking Results Analysis

The proposed methodology that served as the foundation for the two developed heat maps – a general/peripheral view heat map and a *point of regard* heat map – demonstrates the value associated to the use of an eye tracker as well the interesting results that can be generated.

Recalling the heat map in Figure 30, as well as some of the calculated statistics, there were 5 regions of concern: area 7, 11, 14, 16 and 18. Evoking, once more, the number of maximum views in the quadrates of each of these areas; we have 5, 4, 5, 5 views and 1 view, respectively. Therefore, 3 of these regions caught on average just over 40% of the players' attention; one of the regions a third of the players' attention and finally, one of regions claimed a single player's attention. Furthermore, and counting the total number of quadrates that received at least half of the hardcore players' views (quadrates with 7 to 12 visualizations), the total number is lower: 37%.

Figure 32 - Parking lot area in CoD 4 [Area 14 in Figure 30]

These values indicate, without doubt, that much of the map was under-used and passed unseen by the majority of the participants. The general view heat map, in addition, demonstrates that despite some concentration of visual activity in the centre of the map, the peripheral regions of the map represent sections with less interest and even more alarming, no visual attention at all.

Area 1 represents the part of the map where one of the team starts whereas area 14 represents the location where the remaining team starts. As expected, these territories are on opposite sides of the map avoiding, therefore, that one team encounters another moments after the game begins. As can be seen, both these areas register small amounts of visual activity. Surprisingly, however, none of the visual activity registered in these regions is the consequence of the player, once having begun his/her game, exploring the area in which he/she started. Instead, the reason that there are up to 6 visualizations in area 1 and 5 in area 14 is the result of indirect visualizations. That is, during the game, players would look up the hill – positioned in the quadrates near or in area 5 – to the scenery present in area 1, where the scenery is composed of buildings and also where bots are deployed. The same logic is valid for area 14; once players would initiate their game, the tendency was to look straight towards the buildings that were located directly in front of the location in which they started. A second explanation for the quantity of visualizations in the quadrates that make up area 14 is the fact that, when players were positioned to the right of marker 12, these would look to area 14 as seen in Figure 32.

Figure 33 - Scenery only seen by one participant [Area 18 in Figure 30]

The number of visualizations associated to areas 7 and 16 are in some way similar to those just explained. Area 7 was subject to some visual activity not only because players would enter that same region and explore, but also because on occasion, and from more distant regions such as 5 and 6, players were able to see all the way down the road to area 7. Area 16 is, once more, the result of the same rationalization; the build-up in the total number of views was not only due to exploration of the respective area but also because of extended views from players circulating in areas 15 and 17. Finally, as mentioned, area 18 was visualized only on one occasion; that is, by one player. Other than the referred player, this area, as seen in Figure 33, which represents just over 5% of the map, remained insignificant and was not visualized.

Figure 34 - Structure located in front of temple [Area 11 of Figure 30]

For a video game developer, all of the areas in the game environment that received a smaller number of visualizations are of concern. However, examining some of the graphical elements that compose the scenery of the referred areas, the lack of activity in some of these regions is more understandable and justifiable than others. Furthermore, the percentage of these "less viewed" areas can be determined as well as correlated with the point of regard representation map. Therefore, observing the various typologies of scenery that make up the map, some are graphically more complex and consequently, were the result of a greater investment from part of the environment designers.

Exemplifying, looking at the scenery in area 11, it can be said that great effort was put into designing the structure composed of arcs standing in front of the temple as seen in Figure 34. Nonetheless, and bearing in mind the setup of the game presented to the participants, this graphically rich area did not appeal to a great number of the players. Therefore, the question that emerges, for this scenario and for all of the other under-explored and visualized areas is: *Why was this area not viewed? What in/about this area was less appealing than the others?* Most importantly, the question that should be placed is: *What can be done so that these areas are more appealing and enjoyed by the gamers?*

Moving forward, the areas with the greatest amount of activity and therefore, the largest number of visualizations were: areas 3, 5, 9, 10 and 15. The number of visualizations in area 3 is the result of, similarly to what was seen earlier for area 1, players looking downhill to area 5 as can be seen in Figure 35. Therefore, just as players would look uphill from area 5 to the quadrates composing area 1, in this case, players would stand in area 1 and visualize the quadrates that make up area 3 as well as many of area 5. The quantity of activity in area 5 is the result of two factors: the first, as just explained, is directly related to the fact that players that began their game in area 1 would either look downhill or move around in that particular part of the region before moving on to the main street (area 9). In addition, this area was also seen by players that moved around in areas 6, 9 and 10; looking to attack the flag in area 4. Area 9 was in fact the most active of all the regions of the map. 8 of the quadrates in the nearby area were seen by all twelve participants while other nearby quadrates up to 11. The reason behind such great affluence is, as expected, its central localization. To reach all three flags on the map in area 4, 10 and 15, players inevitably had to pass this central region and consequently, it became an active visualized area.

Figure 35 - Player looking downhill to the main street from area 11 to areas 3 & 5 [Figure 30]

Breaking down some of the various courses of movement players would follow to the various flags, we can see the following: if a player beginning in area 1 wanted to capture a flag in area 15, he/she could quickly take the path that covered areas 1-3-18-16-15. However, due to the lack of activity in area 18, that option would naturally be a player's last preference. Therefore, the tendency would be to go downhill, beginning in area 1 and passing areas 3-5-9-15. If the player then decided to attack the flag in areas 4 or 10, once again, they would inevitably have to pass near or on the central street and consequently would visualize those quadrates. As a result, due to the location of the flags on the map, moving in the central street, as seen in Figure 36, or viewing it from a nearby area was, most of the time, inevitable. Area 10 represents the region where one of the flags was localized and, as seen by the quadrates inside the circumference, it was the most active of the three flag-bearing regions with up to 10 participant visualizations. Area 10 was in fact the most active of the flag-bearing regions due to its central an equidistant localization in terms of where the two teams began the game. After beginning their game, players of the team commencing in area 1 could attack the flag in area 4 while players beginning in area 14 could go after the flag in 15 and then on to the flag in 10. Interesting enough, this strategy did not present itself as the players' first options. The common verified tendency was for players to attack the central flag and leave the flags closest to their starting points as secondary objectives. However, whatever the strategy used, the fact is that area 10 was the region whose flag was in constant battle and therefore the number of visualizations in this area is greater when compared to the rest. As mentioned, the general strategy of players beginning in area 1 was to go downhill and attack the flag in area 10. With that thought in mind, the lack of activity in area 4, where one of the flags was located, is somewhat understandable. However, the reason behind this choice is not clear. A possible answer is that this area is in some manner closed off by walls and that the closest entry point – the opening under number 4 – was felt to be a disinteresting detour. Furthermore, it can also be hypothesized that, bearing in mind the players played on a team with bots with artificial intelligence, they believed that the bots would naturally try to capture the flag closest to their starting point. If so, they would leave the flag in area 4 to their team-mates and move on to the next-closest flag, in area 10. Area 15, however, was more active than area 4. Nevertheless, the action that resulted in the build-up of visualizations in this region was not only the result of an attack/defend-the-flag strategy from the players. Rather, on many occasions, when one of the players died, they would respawn[26] in that area and consequently end up visualizing the nearby area in which they were placed.

Figure 36 - View of the central street [Area 9 in Figure 30]

[26] Respawning can be defined as the recreation and insertion of the/a player after its death or destruction.

Moving on to the analysis of the second heat map, as mentioned when first presented, this heat map is the result of representing on the grid the exact locations or elements the various participants were looking at for the various samples taken, as seen in Figure 37[27]. This heat map demonstrates the true potential of the use of the eye tracker; while the first heat map could have been elaborated using any video with a player's in-game performance, this heat map was built on visualization information only the eye tracker could offer.

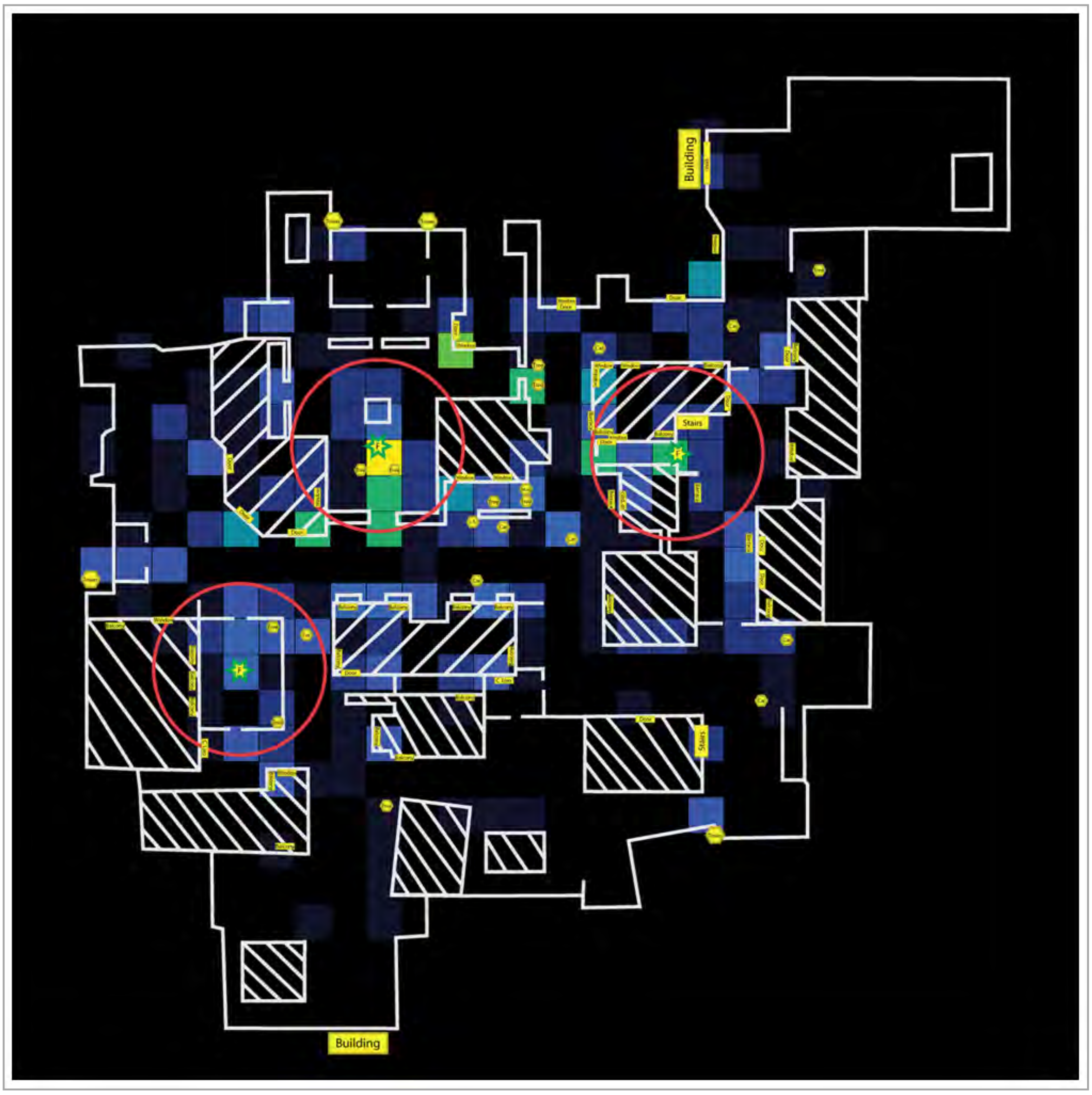


Figure 37 - Heat map representing hardcore players' point of regard (12 participants) with indication of elements

The first heat map, as seen, indirectly issued several warnings about how the maps that are developed are not always used to their full potential. This heat map goes even further as it indicates just exactly what the players look at and therefore, also disregard.

In terms of elements that captured the players' attention, the most obvious are the three flags that are dispersed throughout the map. The quadrate that held the flag located to the left received 4 views; the

[27] For a larger and more detailed view of Figure 37 consult Appendix 5 – Peripheral vision and point of regard heat maps.

central flag, positioned in the most active of the quadrates of the map, received 9 views; finally, the flag to the right received 6 views. In addition to the flags, many of the nearby quadrates located inside the represented circumferences received a significant amount of views.

In the circumference found on the left side of the map, apart from the flag itself, balconies and trees were also viewed. In fact, the two trees in that area were seen by two and three participants, contradicting in some form the idea that trees do not influence eye movement. Recalling the answers in the questionnaires, although the majority of the hardcore players indicated that trees had little or no influence over eye movement, 3 participants did affirm that in fact trees influenced their eye gaze whereas a fourth player indicated that they influenced greatly. Furthermore, four other quadrates that held trees were also the centre of attention for other hardcore players. Balconies on the other hand, as answered in the questionnaires, were one of the elements that participants indicated as influencing eye movement; this heat map confirmed those answers. Moving on to the central circumference, the quadrates that compose this area also received a diverse quantity of views from the players. The two quadrates just below the one holding the flag, received each 6 views. Bearing in mind that these quadrates represent the entry/exit of that area, this elevated number of views could be the result of players concentrating on the area as to not be caught off-guard and therefore be killed by enemies that could appear in that entry. The statue behind the flag, oddly enough, only received 4 views. Considering its size and stature, it would be expected that such an element would have received an elevated number of views. To the top right of this central flag are two quadrates that received an equally impressive – when compared to other quadrates – number of views. One of those quadrates received 7 different player visualizations mainly because of the presence of a door; the second quadrate received 6 views which can be justified either by the fact that the players looked at the tree present in that quadrate or because they looked at the opening to the street. The circumference around the flag on the right side of the map contained various elements that caught the attention of the participants' eyes: a vending cart that one person viewed; balconies and doors on various quadrates as well as a set of stairs that led into the building just above the flag. In fact, balconies, windows and even stairs (not mentioned in the questionnaire) are distributed throughout the map and it is this dispersion of elements that contributed to the variety of quadrates (even if reduced), that received a least one view. However, it must be indicated that many of the quadrates that did not receive a single view represent the streets of the map, parts of the scenery that normally aren't subject to great visual interest if a *point of regard* analysis is being made. Nonetheless, it is possible that the streets of the map be visualized if a general view analysis is made, as seen previously in the peripheral view heat map, where the center street was the most visualized area.

Each label on this map represents at least one view from a participant; existing, however, the possibility that one of the elements (e.g. stairs, cars, windows) was seen by more than one player. A more detailed look at the quadrates with labels representing the various elements of the map of environment can be seen in Figure 38.

It is a fact that there is a great quantity of elements that were seen by various participants. However, the labels placed on the map only account for a portion of all the elements that compose the map. Looking at some of the statistics; 19% of the map was only seen by a single player while 11% was seen by two. More preoccupying is the near 60% of the map that was not even seen once through direct vision. Although not having been counted, if the 40% of the map that was seen at least once (other quadrates were seen by more participants) resulted in over 80 viewed elements (e.g. windows, cars, doors, and others) one can assume that the number of unseen elements of diverse nature is far superior.

The total production cost of the video game Call of Duty 4: Modern Warfare can only be imagined to be very significant. When the peripheral vision heat map demonstrates that 25% of the map and game environment was only seen by a single player or no players at all, the CoD4 development team should question why. Despite the fact that the Strike map is only one of the various maps present in the game and, although these results are specific to the nature of the task that was carried out, one quarter of the map not having been seen is a factor of concern. When the detailed view heat map indicates that over ¾ of the map and game environment was only seen by a single player or no players at all; should the development team not be concerned that their efforts and work, in specific situations, is not sufficiently appealing to the audience? Of course one could contradict this idea with the argument that these results are specific to the setup of the task (the game mode, the map, the reduced number of players which results in less views as oppose to a greater number of players resulting in a hypothetically greater number of views); however, there are no guarantees that similar results would not be acquired even with a different mode, a different map and a greater number of players.

The facts have been presented and the results are convincing; however, as just mentioned, the acquired results are the outcome of a specific situation and a specific setup. For that reason, it can't be denied that a different mode on the same map could have resulted in a completely different heat map. For example, if the *Free-for-All* mode in which the player didn't have any other objective except to kill enemies was played on this map, this setup might have produced completely different results: the map could have been more thoroughly and evenly explored, or possibly; areas of the map that were visualized might have received less visualizations whereas areas that passed unseen, may have been not.

This is to say that, despite the validity of the facts and the obtained results; these must be analysed in the context in which they occurred and it is all but impossible that different results can be obtained.

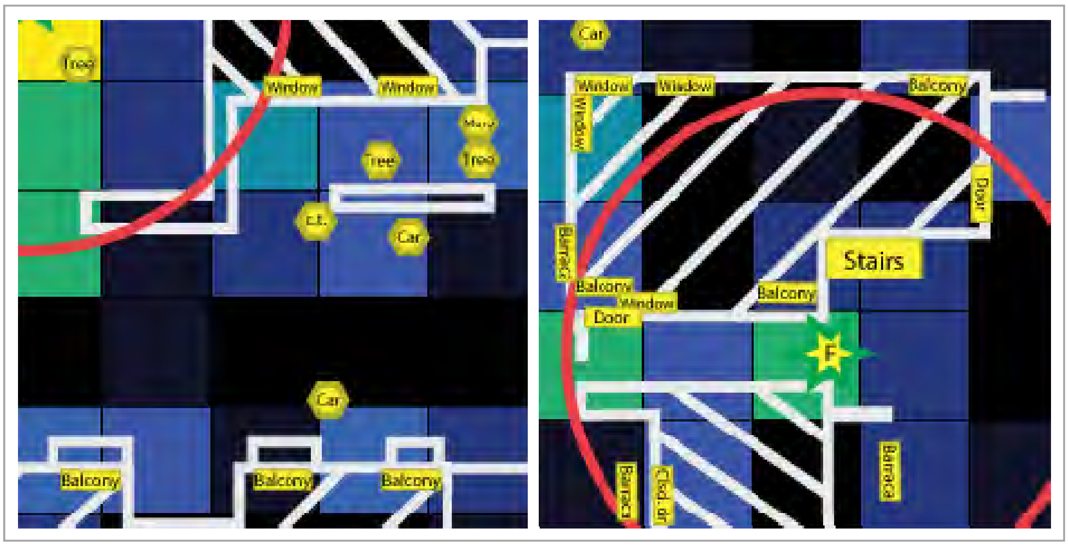


Figure 38 - Detailed view of the element labels present on the point of regard heat map

With these ideas at hand, the following step in the study is to take the acquired results and with these, analyse in what way they can contribute to the development of guidelines for augmenting video game development, the greater objective of this study.

8.4. Materialization of Guidelines

Having concluded the study and thoroughly analysed the results obtained via user feedback, analysis of the heat maps and other opinions; a series of guidelines are now proposed with the intention of serving as a basis for augmenting video game development.

The presented guidelines were elaborated bearing in mind the nature of the game at hand and therefore, many are only applicable to First-person shooter video games. However, others are of generic nature and should be considered as valuable for video games of other genres as well. Furthermore, the presented guidelines were grouped into the Game Categories presented by Desurvire et al (Desurvire, Caplan, & Toth, 2004): Game Usability, Game Mechanics, Game Play and Game Plot. No guidelines were defined for the Game plot category.

Game Usability

- **Game feedback should be immediate**.
  When playing and interacting with elements of a video game, players should not have to waste time questioning if their actions had a result on the game.

- **Game feedback should be presented through various modes.**
  When playing a video game, visual and audible feedback should be presented to the player.

- **Game feedback: when interacting with an object, show complementary information relative to the object.**
  When a player is interacting with an object, provide the player with complementary information related to the same object.
  E.g.: Weapons - image of weapon appears in corner; remaining ammunition; total ammunition that can be carried; weight; origin of gun, year of fabrication.

- **Game feedback: when firing upon an enemy, visually indicate the outcome of the action.**
  When players fire upon an enemy, and if the enemy is hit, indicate the dimension of the injury. *E.g.: Cross over head; visual and audible information when the enemy is killed.*

- **Game interface should interfere with gameplay as less as possible.**
  The elements that compose the game interface should not complicate and interfere with a player's task.

- **Interface elements should have less opacity as to not be confused with the game environment.**

- **Game interface and HUD – *Heads-Up Display* – should be customizable to fit player's needs**. The player should have control over what elements are present on the interface and HUD as well as how (deploy with the pressing of a key or button) and when they are visible

- **Participant score should always be identifiable**.
  When in team play, a player should be able to identify respective team score from opposing team score.
  E.g.: Identification through contrasting information; identification through team names.

- ***MULTIPLAYER*** **- Changes in team scores should be more evident.**
  When one team surpasses another, visual and audible feedback should indicate this change in state.

- **Remaining game time should always be present.**
  A player should have immediate access to the remaining time (for the game or to complete an objective), even if hidden and deployed through the use of a key/button.

- **Provide visual and audible feedback for changes in game time.**
  When playing using *time*, provide the player with visual and audible feedback indicating the current state of the time.
  E.g.: Identification through audible feedback: "one minute remaining"; identification through visual feedback: change in colour; change in text size; zoom in/zoom out.

- **Use sound dynamically for feedback.**
  Make use of the left and right channel to indicate areas in which there is gunfire.
  E.g.: If there is action occurring to the left of the player's presence in the game environment, use the left sound channel for a greater game dynamic. If the action is occurring to the right of the player, use the right sound channel.

- **Game objectives should always be present.**
  A player should have immediate access to game objectives even if hidden and deployed through use of a key/button.

- **Indicate presence of other players.**
  Allow the option to select auxiliary indication of player presence, whether team-mates or enemies.
  E.g.: Identification through audible feedback: "enemy approaching"; identification through visual feedback: indication of "enemy approaching" on interface or on mini-map.

- **Player should have control over game and be able to save game at different moments as to resume play when desired** [*applicable only when in single-player mode*].

Game Mechanics

- **Game controls should be customizable**.
  General game controls should be accessible and customizable without having to leave game.

- **Game Artificial Intelligence (AI) level should be customizable.**

- **Game difficulty should be customizable and recommended to player through a series of pre-tests.**

Game Play

- ***MULTIPLAYER* - Randomization of team starting points.**
  Allow the option for randomizing team starting points as to create greater ambiguity of where player's will be found, maintaining only a minimum starting distance between teams.

- ***MULTIPLAYER* – Randomization of localization of flags on maps.**
  Allow the option for randomizing the location of flag placement on the maps as to create new and different routines and to explore full areas of the game environment and map according to a pre-elaborated interest point list [*option specific to game modes using flags*].

- ***MULTIPLAYER* - Quantity of objects/obstacles in the game environment should be customizable.**
  For specific game modes (multiplayer modes) allow the option to customize the quantity of objects/obstacles in the game environment as to fit user's experience level and needs.
  E.g.: Control quantity through a specification of percentage or element density.

- **Tutorials and training should be available for players with less experience as to shorten the learning curve.**
  Provide players with a series of tutorials and training modes with objectives and information similar to those found in the game as to shorten a player's learning curve. When a player cannot successfully engage in the game because he/she does not understand the mechanics of the game, the player becomes inpatient and on occasion, will give up.

- **Allow spaces and elements to be more dynamic as to add more exploration and excitement to the game.**

As can be seen, many of these guidelines focus on some of the core issues discussed throughout this dissertation; namely some of the questions presented in the questionnaires, such as feedback. In fact, questions related to feedback were some of the most discussed and therefore a compilation of some of the most productive analysis were transformed into the guidelines presented.

part three
study conclusions

9. Conclusions

Having terminated the empirical study and thoroughly analysed the achieved results, final conclusions regarding the study are now made.

9.1. Research question analysis

Recalling the research question presented earlier in this dissertation, *in what way can the analysis of the ocular globe movement contribute to the development of guidelines that can assist in the evaluation of enjoyment in video games?;* it is fair to say that the results obtained via both the questionnaire and eye tracking instruments provided valuable data that can respond to the referred question.

An eye tracking system, such as the one used in this project, provides a vast quantity of results related to a player's eye position on the screen when playing a video game. Any player can indicate verbally what and where they were looking at while playing. Nonetheless, these answers, if acquired after playing, can be influenced and not completely correct. However, only the eye tracker can indicate with precision exactly where and what a player was looking at, at any time in their participation.

Therefore, via the analysis of a player's ocular movement which translates into where on the screen the player was looking at; and furthermore, analyzing players' opinions on what they feel has a greater influence over their eye movement, their choices in avatar movement as well as other indications, it was possible to elaborate a collection of guidelines that can assist in the evaluation and development of video games.

9.2. Research objectives analysis

The study at hand presented a group of objectives that were pursued as they were vital for its success. Having terminated the study, the completion of these objectives is now analysed.

The presented study focused not only, but mainly, on the eye tracking technology. Hence, the identification of the potentialities associated to the use of the technology as a method of usability evaluation was necessary. As seen in sections 3.2 and 3.3, eye tracking presents limitations but it also presents qualities which can be applied in the most diverse areas of study, including usability evaluation.

A second objective implicated the identification of the currently used methods of usability evaluation in video games. Once again, a handful of some of the existing state of the art, research and development projects related to the area were presented. Furthermore, two distinct categorizations of usability evaluation methods were presented: those that use eye tracking and those that do not.

The third objective of the study was to identify and build a study case. As can be seen in *part two* of the dissertation, an empirical study was conducted. A target group of participants was defined; a study object was chosen; an empirical study laboratory was set up; tasks were executed and monitored on the eye tracker; questionnaires were administered; and finally, results were analysed and discussed.

A direct result of the mentioned objective was the next objective: evaluate and validate a video game evaluation methodology. As will be examined further on in this section of the conclusions, it is believed that in fact a video game evaluation methodology was built and that the results it presented are of value, specifically concerning the validation of the game universe and scenery (both environment and architecture) as well as its development strategies.

Finally, the last objective of the project was to elaborate a series of guidelines that could be used in the development of video games and the evaluation of video game enjoyment. As presented earlier in this dissertation, this objective was achieved as a number of guidelines were proposed having taken into account personal observations and opinions, participant feedback as well as direct results from those achieved with the empirical study.

9.3. Validation of proposed methodology

This study enclosed two separate methodologies. The first and general methodology served as the backbone for the entire study and included two main stages: first, the research for the *state of the art* section, and second; the collection of data through the use of the inquiry and observation techniques, which in turn ended in the use of the questionnaire instrument. In addition, the general methodology included the execution of a case study and the acquisition of results. With that in mind, it must be said that the elaboration of the case study permitted the development of a second methodology that is, in some manner, the general result of the project. Furthermore, considering the results – the heat maps – obtained via the second methodology, one can believe that in fact the general methodology that was applied and served as the spine of this project was successful.

However, at this moment, it is the methodology that was developed to create the heat maps and consequently construct the guidelines as proposed in the research objectives that is subject to validation.

Recapitulating the methodology; using the hardcore players' recordings, instances of these recordings were selected every few seconds according to a determined sampling frequency. With the selected samples, the players' positions were represented on an illustrated representation of the map used for the study. Along with representing their positions, the element used to represent their position also served as indication of what parts of the map were in their line of sight as well as what exact game element they were looking at, at that precise moment. With this data in hand, two heat maps were built. The first represented the summary of the players' general and peripheral views; the second, their point of regard.

Having seen and analysed the results, it is fair to say that in fact the methodology is valuable. The heat maps that result from the application of the methodology indicate what parts of the map were seen and what parts weren't. And these indications are, if not essential, very useful for video game development companies. However, and as mentioned at the time, these results are promising and the methodology should be applied in a proper game development context with a larger group of evaluation participants.

The question that can be asked then is: *is eye tracking in fact a valid technique for usability evaluation (or for assessment in general) in a video game context?* The answer, as has been demonstrated with these preliminary tests, is yes.

When compared to other techniques such as heuristics, eye tracking can be just as valid as any technique for a determined situation. Heuristics, for example, can indicate the best solutions for the development and evaluation of certain aspects but, on the other hand, do not always contemplate user input; they are based on expert opinions and are not completely up to date with player tendencies.

What these maps demonstrate is player interaction with the game; they were built having considered players' movements and visualizations in the environment: what places they visited and what places they didn't; they were built on user input. The indication of what parts of the map are *used* and what parts aren't can in turn be translated to what is or not appealing to a video game player.

In conclusion, these results have demonstrated the value of the eye tracker as a method to evaluate usability, namely in a video game context. Furthermore, considering that the origin of these results is in part related to the information collected via the analysis of the ocular globe movement, the first hypothesis presented in section 1.4.4 – Model of Analysis – has been confirmed. The same can be said for the second hypothesis. The present study has demonstrated that existing usability research and evaluation methods are in fact valuable for video game development. This was possible through an exhaustive description of some of the existing research and their application in the industry. Finally, the present study has also shown that ocular globe movements (eye movements) can be tracked, identified and present themselves as a method for understanding enjoyment in video games; confirming therefore, the third hypothesis.

Nonetheless, the enjoyment in video games goes beyond the range of eye tracking and other methods are essential for a complete understanding of video game enjoyment. However, optimal conditions to elaborate adequate guidelines and strategies for video game evaluation and assessment should always consider more than one method as these, together, offer complementary data. Traditional evaluation methods should not be considered incompatible nor should the validity of the input of eye tracker data be rejected. Instead, all the methods at the disposal of a researcher and video game developers should be considered when elaborating a usability study to assess the quality of a video game.

9.4. Contributions to research area

Video games and usability are two concepts and research areas that have been the object of exploration and research for the past years, independently and more recently, as a whole. Therefore, the study of just these two elements would have not made much sense if a third factor was not introduced into the equation: eye tracking.

In fact, it was the joining of these three elements in one study that has resulted in a contribution to the research area. The number of existing studies that have approached video game evaluation and development through the use of a technology over which many hesitate, is limited.

In addition, the definition of a new methodology that can be used to better develop and evaluate video games is the largest contribution to the research area at hand. Along with this methodology, and to conclude, the elaboration of a series of guidelines that can also assist in augmenting video game development can be considered as a final complementary contribution.

Furthermore, the present study has demonstrated that in fact eye tracking and eye tracking data is of value in the usability research field. Therefore, this study can be seen as another element of proof that in fact existing criticism relative to eye tracking is exaggerated and that in fact this technology is of significance in the usability research area.

9.5. Study limitations

Considering the limitations found during the study, the number to consider is reduced. One of the limitations of the study that, nonetheless, is believed to have been sufficiently controlled, was the technological limitations that in some manner conditioned the case study. The complexity of a video game resulted in a more complicated use of the eye tracker, complications that would not have surfaced if the media involved was static, such as a website. However, this minor limitation was overcome as was described in the appropriate section of this dissertation. Nevertheless, the limitations were felt by some of the participants.

A second limitation encountered during the study was time-related. As referred in the dissertation, the heat maps were solely based on hardcore participants' contributions. Although this scenario was predicted, a greater amount of time to analyse results could have created conditions for heat maps of the three distinct categories of players to have been built and consequently, analysed and compared for a better understanding of how players with different experiences visualized the environment and move around the map. Furthermore, the analysis of the second map (District map), independently of the game mode played, could have returned other results of interest to the study.

9.6. Perspectives for future work

Having terminated the presented project, many questions surface regarding not only how this project can be applied in the areas to which it is directed but also, how the project itself could be better.

There are, therefore, many possibilities for future work. As just mentioned above, the development of distinct heat maps for the various categories of players is a possibility. This would not only make the work itself richer, but would contribute with interesting findings of how each category of players explores and views the maps. Also, the possibility of reconsidering the number of instances marked on each player's recording timeline could benefit the crafting of the heat maps, especially the heat map focused on specific player views. The elaborated heat map presented in the study was based on samples taken, on average, every 5 seconds. If this number was reduced to two, then the number of specific places seen on the map would change drastically. However, the general heat map would probably not suffer many changes.

Another possibility is the use of a different game map as well as a different game mode. As mentioned earlier, the obtained results must be kept within the context in which study was executed. Therefore, it is natural to think and believe that a different mode played on the map used to construct the heat maps could have produced completely different results; just as would the use of the same game mode on a different map or a different game mode on a completely different map. The combinations, bearing in mind the total number of maps and modes Call of Duty 4 offers is vast. Therefore, it would be interesting to explore different solutions and analysed the acquire results.

A final input on future work is something that requires much more patience and dedication. The presented methodology that was the foundation of the heat maps was all done manually; from the marking of the players position on the map, to the rotating of that marker so that it is in harmony with what the player saw during the game; the creation of the grid and the codifying of the quadrates to build the heat map was all manual work. With access to an "open" Call of Duty game, the heat map development and processing method would be automatic and constructed with the interconnected processing of eye tracker and Call of Duty log files.

Therefore, the conception and development of an algorithm or program that could absorb the information offered by the Tobii Studio software and the Call of Duty game and translate it into a heat map similar to those manually built is a challenge that could be set for the future, so that studies of similar nature can benefit, not only in terms of time, but also in terms of results.

9.7. Final thoughts

In the beginning of the present dissertation, the numbers relative to the video game industry were presented: $46.5 billion dollars in sales by 2010. This astronomic number offers no doubts that the industry is growing and will continue to do so. Presently, video games aren't just a source of entertainment for children. More and more people of various ages are beginning to engage in this phenomenon that in the past was only enjoyed by people of specific ages. Video game developers have demonstrated the perspicacity of understanding what *gamers* want and also how to attract those who do not traditionally play. However, despite this aptitude, video games are still being developed for the *sake of it* and without having gone through a proper evaluation at various instances of their development or before their release.

This study and dissertation is not an alert at the fact that many video games fail to entertain because of unsuccessful development and/or evaluation. However, it is an alert for the fact that video games can be improved if studies such as this one are analysed to understand player tendencies, opinions and input. It can't be forgotten that *gamers* are a video game's end target and if their opinions are simply overlooked then many video games will continue to fail. A *gamer's* opinion should be considered as important and just as valid as an experts because their input results from a different type of experience, a hands-on experience; one that many experts lack.

The presented study has, in fact, taken into account various players' – with different gaming experiences – opinions and input, and together with the use of a *new* technology – eye tracking – created conditions for the development of guidelines that can be used by video game developers to augment video game development and, if desired, evaluate video games.

Finally, it must be said that video games will never be flawless and even in the presence of a near perfect game; players will continue to elevate their expectations and demand more enjoyable video games. This study has not produced a methodology that can help deliver perfect video games but has, nevertheless, presented ideas that can help overcome that challenge.

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11. Appendix

Appendix 1 – Questionnaire used in empirical study

Due to the size of the questionnaire and to facilitate its lookup, it was believed that it was preferable to present it in a digital PDF format.

Therefore, the questionnaire can be found in the folder ***appendix 1 - questionnaire*** found on the CD accompanying this dissertation.

Appendix 2 – Call of Duty 4: Modern Warfare Game modes, maps & acts[28/29].

Game Mode	Description
Team Deathmatch	Use teamwork to kill opposing players and reach score limit.
Mercenary Team Deathmatch	Use teamwork to kill opposing players and reach score limit. Teams are randomized.
Free-for-All	Every player for him/herself.
Domination	Flags are placed at certain points around the map. All flags start neutral. Players fight to hold the most flags. The match ends when the time limit or the score limit is reached.
Ground War	A combination of Domination and Team Deathmatch. The score limit for Team deathmatch is 1000 points.
Sabotage	Similar to Search and Destroy, except that the bomb is neutral. Players must take the bomb and plant it at objectives located in the enemy team's base. The bomb carrier can fire his weapons, but his/her position will be announced periodically throughout the game. Also, unlike Search and Destroy, players will have unlimited respawns as opposed to just one per round.
Headquarters	A laptop is randomly spawned on the map. Players must capture the laptop by staying near it within a certain amount of time; the more friendly players are near the laptop, the faster the laptop is captured. Players earn points for every 5 seconds the laptop is held.
Search and Destroy	This mode plays almost exactly like *Counter-Strike*'s classic bomb planting mode; two teams of players will play as either attackers or defenders. Attackers will try to plant a bomb at one of two bomb sites, and defenders will try to defend the bomb sites. If the explosives are planted, the attackers and defenders switch roles as the attackers must now defend the bombs from the defenders, who will try to disarm the bomb. Players do not respawn. A round is over when all players on one team are killed, or when the bomb successfully detonates or is defused.
Team Tactical	Small team games that play Team Deathmatch, Domination, Headquarters, Sabotage and Search & Destroy.
Hardcore Team Deathmatch	This is the same as Team Deathmatch, except that player health is lowered and the HUD (Heads-Up-Display) is removed.
Hardcore Search and Destroy	This is the same as Search and Destroy, except that player health is lowered and the HUD is removed.
Old School	This is a Free-for-all mode featuring increased health, higher jumping, unlimited sprint, doubled magazine capacity for all weapons and no class selections.
Cage Match	One on one deathmatches (Fight to the death). Many people like to use this game to play with their friends, taking turns getting headshots to get the popular red tiger on guns. This is best known as "boosting". Score limit: 50 points. Kill: 5 points.
Hardcore Headquarters	Recently added, it's basically just Headquarters, but player health is lowered and the HUD is removed.

Table 5 - List of Call of Duty 4 Game modes and description

[28] Call of Duty 4: Modern Warfare game modes, maps and acts differ from platform to platform.
[29] CoD4 modes, maps and acts [Retrieved from: http://callofduty.wikia.com/wiki/Call_of_Duty_4:_Modern_Warfare; February 11, 2009]

Map	Description
Ambush	Large desert town. Excels in Sabotage matches.
Backlot	Medium sized construction site and town. Great map for any mode.
Bloc	Large Ukrainian apartment bloc very close to Chernobyl. Intense Domination matches.
Broadcast	Fairly Large television broadcast center. Good for most modes with plenty of people. (Only available after buying the Variety Map Pack)
Bog	Small desert bog. Open level, excellent for smaller groups.
Chinatown	Large Town. Windows/buildings everywhere. (Only available after buying the variety map pack)
Countdown	Open launch pad. Huge sight lines and dangerous manoeuvring.
Crash	Downed Sea Knight in a desert town. Fantastic team games.
Creek	Big map of the great outdoors around a creek. Great sniping spots. (Only available after buying the variety map pack)
Crossfire	Small desert town. Intense interior fighting and strong firefights.
District	Large urban town with a market in the middle. Great for team games.
Downpour	Big rainy Russian farm. Excellent for Sabotage matches.
Killhouse	Tiny SAS training facility. Only good for small number of players. (Only available after buying the variety map pack)
Overgrown	Large overgrown rural Russian area. Sniper ghillie suits make for good concealment.
Pipeline	Russian trainyard. Excellent team games.
Shipment	Tiny Russian shipyard. Fast paced action with no hiding.
Showdown	Small desert arena. Great fast gameplay for small numbers of players.
Strike	Large urban desert town. Excellent team games.
Vacant	Deserted Russian office. Intense interior fighting.
Wet Work	Medium-large cargo ship. Fast-paced Search and Destroy matches.
Winter Crash	Crash at night with snow and a Christmas tree in the middle of the map (Only when multiplayer upgraded to 1.4 version) (Christmas time special) (PC only).

Table 6 - List of Call of Duty 4 Game maps and description

Act	Mission	Character used
Act 1	Crew Expendable	Sgt. “Soap” MacTavish (SAS)
	Black Out	Sgt. “Soap” MacTavish (SAS)
	Charlie Don’t Surf	Sgt. Paul Jackson (USMC)
	The Bog	Sgt. Paul Jackson (USMC)
	Hunted	Sgt. “Soap” MacTavish (SAS)
	Death from Above	Thermal Imaging TV Operator
	War Pig	Sgt. Paul Jackson (USMC)
	Shock and Awe	Sgt. Paul Jackson (USMC)
Act 2	Safehouse	Sgt. “Soap” MacTavish (SAS)
	All Ghillied Up	Lt. Price (SAS)
	One Shot, One Kill	Lt. Price (SAS)
	Heat	Sgt. “Soap” MacTavish (SAS)
	The Sins of the Father	Sgt. “Soap” MacTavish (SAS)
Act 3	Ultimatum	Sgt. “Soap” MacTavish (SAS)
	All In	Sgt. “Soap” MacTavish (SAS)
	No Fighting in the War Room	Sgt. “Soap” MacTavish (SAS)
	Game Over	Sgt. “Soap” MacTavish (SAS)
	Epilogue [Bonus Mission]	Unknown Character

Table 7 - List of Call of Duty 4 Acts, Missions and corresponding used character

Appendix 3 – Player in-game movements

Due to the dimension of the images of the players' movement representations, it was believed that it was preferable to present these in their original size and in digital form for a more detailed viewing.

Therefore, these images can be found in the folder ***appendix 3 - in-game movements*** found on the CD accompanying this thesis.

Appendix 4 – Heat map development

Due to the dimension of the images representing the evolution of the peripheral view heat map, it was believed that it was preferable to present these in their original size and in digital form for a more detailed viewing.

Therefore, these images can be found in the folder ***appendix 4 – heat map development*** found on the CD accompanying this thesis.

Appendix 5 – Peripheral vision and point of regard heat maps

Due to the dimension of the images representing the final versions of the peripheral vision and point of regard heat maps, it was believed that it was preferable to present these in their original size and in digital form for a more detailed viewing.

Therefore, these images can be found in the folder ***appendix 5 – final heat maps*** found on the CD accompanying this thesis.